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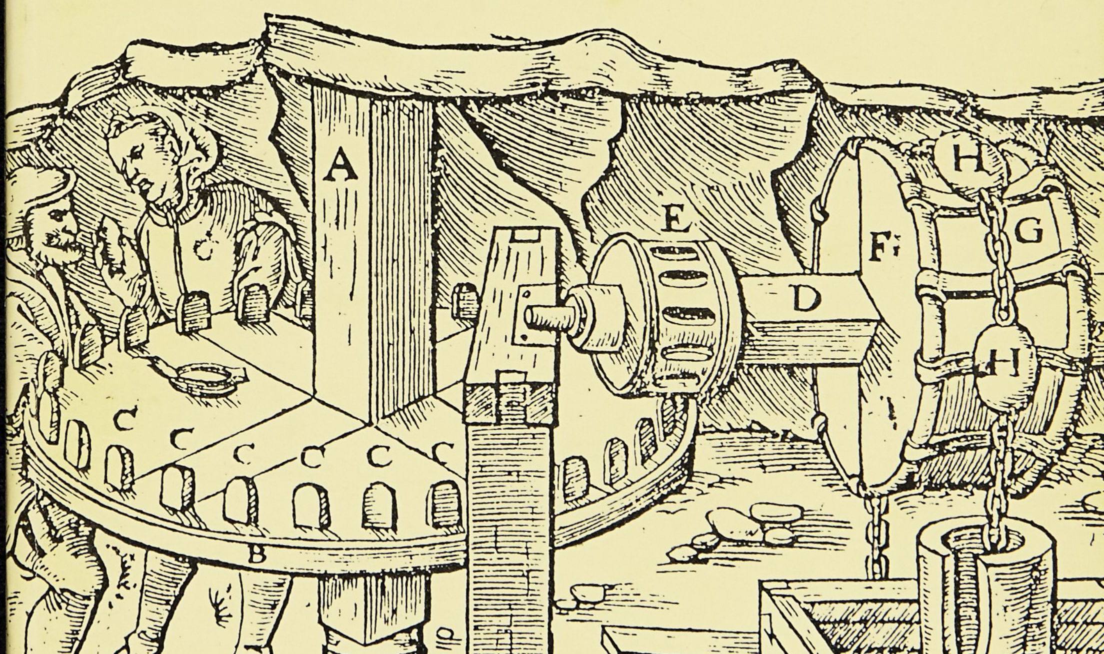

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ANNUAL CLIMATOLOGICAL BULLETIN No. 4 1982

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THE WEATHER OF 1982

This was the sort of year a climatologist really enjoys, when the record books have to be rewritten. The beginning of the year produced the lowest air temperature in living memory over most of the United Kingdom, and was followed by the coldest March since records at Parkhead began. If these were not enough, then there was the driest July since 1970, which was more than matched by the wettest August and November.

January. Exceptionally cold, becoming milder.

The weather remained relatively mild over the first five days as fronts crossed the British Isles, bringing the heaviest rain of the month. A total of 35.2mm fell at Parkhead on the 2nd and 3rd. Snow fell on high ground in Scotland on the 4th while floods affected England. From the 5th, high pressure dominated the weather, bringing in exceptionally cold air from the east. This produced some of the coldest weather this century. Stirling escaped the worst of the snow, which badly affected England on the 8th and 9th, but did experience the extreme cold which culminated in a night-time minimum of −17.2°C on the 11th. The minimum of −27.2°C recorded at Braemar on the 10th equalled the United Kingdom record low temperature. Daytime maximum temperatures at Parkhead remained below freezing on the 9th, 10th and 11th. A well developed anticyclone moved eastwards across the country and into western Europe after the 11th and daytime temperatures gradually improved although nocturnal frosts remained moderate to severe. As the anticyclone eventually moved into eastern Europe, a southerly airstream over Britain brought a rapid improvement in temperature on the 16th, although this was preceeded by widespread fog. Snow in the hills thawed rapidly and it was possible to reach the Ochil weather station on the 18th. A series of eastwards moving fronts brought very dull wet weather for five long days, after which a ridge of high pressure brought a brief spell of fairer weather on the 22nd and 23rd. A well developed ridge of high pressure developed over the Atlantic after the 25th which resulted in a cold northerly airflow over Scotland and a return to night frosts. As the high became stationary to the south-west of Britain, milder weather returned. Exceptionally high temperatures were recorded between the 29th and 30th, in the wake of a warm front. The milder weather in the latter half of the month brought the average temperature nearer to the seasonal normal. 1979 had much lower average maximum and minimum temperatures at 3.6°C and −3.8°C respectively.

February. Generally mild but some cold periods.

A series of deep depressions passed to the north of Scotland during the first two weeks. The winds, mainly from between west and south, were strong at times especially on the 8th, 12th and 13th. Temperatures during the day were well above the seasonal average and on the 5th and 12th reached 10.0°C at Parkhead. A maximum temperature of 9.0°C was recorded on the 5th at Carim. Rainfall was frequent and was recorded on 11 out of the first 13 days. Much of this fell in squally showers which were occasionally of snow or sleet. The pressure pattern began to change on the 14th. With high pressure over northern Britain, night-time temperatures fell sharply under clearing skies, falling to −5.5°C on the 16th. High pressure became established over Scandinavia where it remained until the 22nd. The weather during this period was cold and grey, and fog occurred on the 16th. Little precipitation was registered at either the lowland or upland stations. Night frosts occurred as a ridge of high pressure extended north-eastwards across Britain on the 22nd and 23rd but a series of fronts restored mild and wet weather by the 25th. The largest 24 hr. rainfall was recorded on the 28th (Parkhead 12.9mm; Carim 19.0mm).

March. Squally; cold at night.

The first three days were blustery with strong westerly winds and heavy showers. Very strong westerly winds overnight on the 2nd and 3rd caused minor structural damage in the Stirling area. A ridge of high pressure moved across the country from the 4th and as skies cleared night-time temperatures fell sharply on the 5th (−2.8°C at Parkhead; −1.5°C at Carim). With high pressure over the north Atlantic after the 8th, Scotland experienced a cold W/NW polar airstream in which there were squally showers. As a deep depression tracked across Scotland on the 11th and 12th, there were gales and heavy rain. A 24 hr. total of 23.4mm was registered at Parkhead. While pressure gradients remained relatively slack between the 17th and 20th. Stirling experienced some fair weather but with occasionally clear night skies, slight air frosts occurred. An anticyclone became established to the south-west of the British Isles on the 21st which extended over southern England until the 26th. In a mild W/SW airstream Scotland experienced unseasonally mild weather, temperatures reaching 15.4°C at Parkhead on the 25th (12.0°C at Carim). The settled weather pattern began to break down on the 27th. Night frosts returned. A ridge of high pressure developing to the west on the 27th moved steadily eastwards and temperatures fell sharply in a cold polar airstream.

April. Relatively mild and dry.

For the first two days pressure was high to the east and north-east bringing a cloudy E/SE airflow over Stirling. Fronts moved into Scotland from the south-west on the 3rd and lingered for several days, bringing low cloud, slack winds and intermittent rain. A depression and associated fronts moved quickly eastwards across Scotland on the 6th and 7th resulting in a fall of a little over 14mm of rain at both Parkhead and Carim. With an anticyclone developing to the north-west of Scotland, the month's wettest weather came to an end on the 8th. While pressure remained low over Scandinavia, the British Isles were affected by a cold polar airstream in which night-time temperatures fell slightly below freezing. As the low filled, the anticyclone moved eastwards to affect the whole country between the 14th and 21st. The weather over this period was generally sunny and warm although night frosts occurred in slack air on the 18th and 19th. Weak fronts occasionally moved south-eastwards bringing cloud but little or no rain. 1mm was registered at Carim on the 16th, and none at Parkhead. As the anticyclone retreated westwards on the 21st and 22nd, more active fronts brought in heavy cloud, but again only small amounts of rain. The restoration of high pressure on the 23rd heralded the warmest weather of the month. The 24th was calm and sunny and the temperature reached 18.5°C at Parkhead (Carim 16.5°C). High pressure again moved westwards after the 27th and as a deepening depression moved eastwards towards Norway, winds veered to NW, temperatures fell and frontal troughs brought a little more rain to boost the month's flagging total.

May. Cool and wet at first, becoming warmer.

As a deepening depression approached from the north-west, Scotland experienced strong winds and rain over the first four days, with some snow falling over higher ground. The rain was particularly heavy on the 2nd, when 28.3mm fell at Parkhead, and 40.0mm at Carim. As the depression became stationary over the North Sea, and pressure increased over the Atlantic, a cold northerly airstream affected the British Isles, which gradually weakened as the depression filled. Ridges of high pressure extended across Scotland on the 7th, 8th and 9th which brought about an improvement in daytime temperatures. The night-time temperature fell to −2.0°C at Carim on the 7th. As high pressure became established off the east coast of Scotland, milder air from the south improved temperatures, which reached 21.3°C at Parkhead on the 14th. (19.0°C at Carim). Weather patterns became more unsettled after the 14th. The next fortnight was consistently cool, wet and at times windy. Eastwards moving fronts on the 24th resulted in the wettest day of this period (11.9mm at Parkhead). As pressure increased from the south-west on the 28th milder drier weather returned for two days but by the

31st the anticyclone had drifted eastwards into Europe to be replaced by unsettled wet weather.

June. Very warm and dry at first; cool and wet later.

While a broad ridge of high pressure remained over Europe, the British Isles experienced a mild south-easterly airstream. The weather in central Scotland was sunny and warm, and maximum temperatures exceeded 20.0°C on 7 out of the first 8 days. On the 5th maximum temperatures reached 28.6°C at Parkhead (26.0°C at Carim). This was a period of severe thunderstorms and floods south of the border. Pressure began to fall on the 9th and daytime temperatures fell as more unsettled weather affected Scotland. Rain fell from a slow-moving trough on the 11th; 14.8mm was recorded at Parkhead, 24.0mm at Carim. A series of weak depressions moving in from the west brought a period of grey cloudy weather but no rain was recorded at Parkhead apart from 7.0mm on the 16th. Carim station was frequently shrouded in low cloud and, therefore, registered small daily amounts of precipitation. More active depressions and associated fronts moved eastwards across England after the 25th. Rain fell on all the remaining days of the month. The wettest day was the 27th when 17.3mm fell at Parkhead. On the whole, the rainfall total for the month was 118 per cent of the 1971–82 Parkhead average. The most interesting feature was the very marked contrast between northern and southern Britain. The thunderstorms which plagued southern England raised the month's totals to more than 200 per cent of average while northern Scotland remained relatively dry with only about 30 per cent of normal.

July. Warm and dry.

Weather patterns remained unsettled for the first two weeks. Temperatures during this period fluctuated very markedly from day to day. A daytime maximum of 20.6°C on the 6th fell to 14.9°C on the 7th after the southwards passage of cold fronts, only to soar back to 22.1°C on the 8th behind a northwards moving warm front. Skies remained cloudy but rainfall amounts at Parkhead were relatively small. At Carim, small amounts were recorded on 14 out of the first 16 days. Pressure began to increase from the south-west on the 16th and for the next 14 days high pressure was always in the immediate vicinity of the British Isles. Maximum temperatures at Parkhead hit the 20.0°C mark on the 17th and never fell below it for the remainder of the month. The warmest day at Carim was the 20th. Cloud amounts were occasionally heavy, partiularly when weak fronts crossed northern Scotland. The weather patterns began to break down on the 30th as high pressure drifted north-eastwards and pressure began to fall over Scotland, albeit gradually. Outbreaks of rain moved northwards to reach Stirling late 31st.

August. Warm at first, cool and wet later.

The first few days were oppressive with low cloud, but little rain fell. As the clouds cleared, the weather became hot and humid on the 3rd, 4th and 5th. Temperatures reached 26.4°C at Parkhead on the 4th (23.5°C at Carim). Thunderstorms occurred on the afternoon of the 5th, with some exceptionally intense rainfall. 28.8mm fell at Parkhead, but Carim received 55.5mm!! As a weak ridge of high pressure extended northwards across Scotland on the 6th, warm and humid conditions returned but the 7th was a fine sunny day. As a series of fronts moved in from the west, the weather became more unsettled and rain fell early in the morning of the 8th. For the next three weeks, rain was recorded at both Parkhead and Carim on all but 3 days. The greatest rainfall during this period occurred on the morning of the 18th, as a cold front moved south-eastwards across Scotland (14.2mm at Parkhead; 25.0mm at Carim). A ridge of high pressure developing to the west of the British Isles brought cold high latitude air over Scotland from the 19th to the 22nd, which resulted in a sharp fall in daytime temperatures and blustery showers. A deepening depression moved eastwards across Scotland after the 23rd to become stationary to the east of the Shetlands by the 27th. As it moved across Scotland there was a period of heavy rain and strong westerly winds on the 24th. Pressure began to rise on the 27th as a ridge of high pressure extended north-eastwards across the British Isles to give two dry but cold days. Fronts approached in the evening of the 28th heralding a return to wet and windy but remarkably mild weather. Pressure was rising again at the end of the month and the weather became fine again, but temperatures remained low in a fresh W/NW wind.

September. Wet; mild at first, becoming cooler.

A fresh to strong westerly airflow affected most of Scotland for the first few days. Fronts moved eastwards across Scotland bringing continuous rain all day on the 4th when 25.5mm fell at Parkhead and 22.5mm at Carim. Unsettled weather with occasionally heavy showers persisted until the 9th and 10th when further heavy frontal rain was associated with a deep depression to the south of Iceland. A weak anticyclone became centred over the British Isles on the 11th which brought a dry, warm and sunny day. Fronts moved eastwards across Scotland on the 12th bringing further rain in a freshening wind, but as pressure began to rise overnight, colder, more settled weather arrived on the 13th. While pressure over Western Europe remained high, Scotland experienced cloudy and calm but dry weather for four days. Daytime temperatures were relatively high, reaching 22.3°C at Parkhead on the 17th (18.5°C at Carim). A cold front moved south-eastwards across Scotland on the 18th bringing rain, which became heavy and continuous as the front lingered over the borders area. Pressure fell sharply overnight and the 20th dawned wet and windy. For the remainder of the month, the weather was unsettled as a series of deep depressions moved in from the Atlantic. Winds were occasionally strong and the rain heavy. A deep depression centred over the Irish Sea on the 27th brought particularly severe weather for most of the day. 23.2mm of rain was registered at Parkhead, 35.5mm at Carim. As pressure rose on the 29th, calmer weather returned and as skies cleared night-time temperature fell to 2.4°C at Parkhead on the 30th.

October. Dull, wet and windy.

After a dull start the wind freshened on the 3rd to reach gale force westerly on the 4th as a deep depression crossed the British Isles. While amounts of precipitation at Parkhead were small, 11mm fell at Carim. As the depression moved away, Scotland was affected by a fresh northerly airstream on the 6th which gradually gave way to calm and dull weather until the 10th. An Atlantic depression moved eastwards after the 10th, and drizzle fell in a freshening wind on the 11th and 12th, to be replaced by cooler showery weather on the 13th.

As a ridge of high pressure crossed Britain on the 14th and 15th the wind decreased to give calm and clear, typically "autumnal" weather. Another vigorous Atlantic depression arrived on the 16th with attendant strong winds and heavy rain, which persisted for a remarkable three days. The 17th was one of the month's wettest days with 18.3mm falling at Parkhead, and 30.5mm at Carim. Strong south-westerly winds continued unabated until the 20th when a ridge of high pressure began to extend slowly north-eastwards, to reach Scotland on the 23rd. As skies cleared, night-time temperatures fell and the first air frosts were registered at Parkhead and Carim on the 25th. Another vigorous depression passed to the north of Scotland on the 26th and 27th but although the south-westerly winds were strong, little rain fell. High pressure became established over Europe for the remainder of the month and temperatures rose in a mild southerly airstream. As a warm front slowly moved northwards on the 30th, continuous and at times heavy rain fell all day, the wettest of the month at Parkhead (21.8mm).

November. Mild and wet, becoming very cold.

After a fine afternoon on the 1st, low cloud on the 2nd gave way to fog on the 3rd. Visibility was still poor on the 4th but as pressure began to fall improved in a freshening easterly wind. Complex troughs brought heavy rain on the 5th and 6th, the former being the wettest day of the month at both Parkhead (21.5mm) and Carim (28.0mm). A deep depression to the south-west of the British Isles on the 6th and 7th brought a mild southerly airstream across the country, which remained dry until late on the 7th when troughs brought overnight rain. The weather was changeable after the 9th as a succession of Atlantic depressions gave strong winds and squally rain. As high pressure built to the west of the British Isles air began to approach Scotland from a more northerly quarter and by the 13th heavy snow was falling on high ground above about 250m. Air temperatures on the 14th only reached 4.9°C and fell to −1.0°C overnight as the sky cleared. After north-westerly gales and more snow on high ground on the 16th, the return of a more westerly airstream on the 17th brought slightly warmer but very wet and blustery weather for the next few days. As a strong ridge of high pressure developed over eastern Canada and began to drift towards Greenland, depressions affecting the British Isles after the 21st began to draw in very cold moisture laden arctic air. On the 23rd, heavy rain with some thunder turned to snow by mid-day and 5cms or more accumulated in a very short time. By the late afternoon the snow had turned to rain again which cleared during the evening. Under clear skies ground temperature fell to below freezing and black ice was widespread by the following morning. Cold arctic air continued to affect Scotland for the next few days and when skies cleared moderate air frosts occurred. The month's lowest air temperature occurred on the 27th (−4.0°C at Parkhead; −2.5°C at Carim). Frost on the 26th was accompanied by fog. By the 28th, pressure began to increase from the south-west, which brought in slightly milder air and generally poor visibility. Night frosts, however, persisted until the end of the month.

December. Cold and very wet.

While pressure remained high in the vicinity of the Baltic Sea, Scotland experienced a cold light easterly wind. The overnight temperature fell to −5.9°C as the skies cleared on the 1st and daytime temperature rose to a foggy 3.4°C. As the anticyclone began to retreat very slowly, Atlantic weather systems began to advance and the wind veered to a more southerly quarter. By the 4th the wind had freshened and a complex series of fronts brought rain on the 4th. Pressure began to build overnight on the 5th and by mid-day on the 6th, a weak anticyclone lay over the British Isles. Clear skies meant a return to night frosts and Airthrey Loch was partly frozen over. A complex low moved in from the west on the 7th and its associated fronts moved north-eastwards across Scotland bringing heavy rain and strong south-easterly winds. Parkhead recorded a 24 hr. total of 30.2mm, Carim 37.5mm, the highest of the month. Rain turned to snow during the night and by 09.00 on the 8th snow was lying, which gradually melted during the day. Fronts brought more rain on the 9th and removed the last of the snow on low ground. The next few days were cold and grey with ever deepening night frosts. Minimum temperatures reached the month's lowest at Parkhead on the

12th (–6.4°C). After more frontal rain on the 14th and 15th more high latitude air swept across Scotland on the 16th bringing further snow and low night temperatures for the next two days. Daytime temperature only reached –0.2°C at Parkhead on the 17th. By the 18th, a deepening Atlantic depression was approaching from the west, the centre of which fell to a remarkable 932mb off the north-west coast of Scotland. During the 19th and 20th, storm force winds and heavy rain caused structural damage and floods in many areas. As the depression moved slowly towards Scandinavia, Scotland was brought in to a strong northerly airstream on the 21st which persisted until the 23rd, when fronts moving eastwards across the country brought more snow which turned to drizzle by the 24th as temperatures increased. The weather remained unsettled for the rest of the month with periods of drizzle or heavier rain in occasionally strong westerly winds.

Climatological Averages for Parkhead (Table 5)

Climatological averages are usually taken over periods of 30 years in the case of air temperature and 35 years in the case of rainfall. This is because, in Britain, there is a built-in year to year variation in all the parameters which we use to define climate. If we use too small a number of years our average may be biased by one extreme value. As there are only 12 years of records for Parkhead, there is considerable room for error in the calculation of averages. The table of climatological averages for this station should, therefore, be viewed with some caution.

DATA SOURCES

Stirling (Parkhead) Grid Reference: NS 815969
Height above sea-level: 35 metres Established: 1970

Location: University botanical gardens at the eastern end of the campus.
Monthly returns of daily observations are submitted to the Meteorological Office, and the Climatological Observers' Link.

Ochil Hills (Carim) Grid Reference: NN 864049
Height above sea-level: 332 metres Established: 1980
Location: The upper catchment of the Burn of Ogilvie, near to the ruined Carim Lodge. Surrounded by open moorland.
Autographic recording. Site visited weekly. Two new Met. Office Mk.II rainguages have been installed, one at the standard height of 0.3m above the ground surface, and the other at ground-level surrounded by an anti-splash grid. The site is now registered as Met. Office rainfall station reference No. 893421. The station remained snowbound for the first

two weeks of January. Air temperatures for this period have been estimated by cross reference to Parkhead. The current station equipment is soon to be replaced by a fully automatic Didcot Automatic Weather Station linked to a CR21 solid-state logger and memory unit. This will produce a continuous record of wet and dry bulb temperature, wind speed and wind direction, and net radiation necessary for the determination of the water balance of the surrounding catchment area.

Skinflats — Grid Reference: NS 929835
Height above sea-level: 0.4 metres — Established: August 1980
Location: An Automatic Weather Station fixed to a tower on the intertidal mudflats of the Forth estuary, near Grangemouth.
Part of an NERC funded research project. No data summaries are produced. Research project reports available on request. Station destroyed by ice floes in the Forth on January 13th, 1982.

RESEARCH NOTES

The effects of elevation

As indicated in last year's Annual Bulletin, the relationship between weather variables and height above sea-level is by no means a simple one. During this year, the average difference in maximum temperature between Carim and Parkhead was 3.0°C which represents a lapse-rate of 10.1°C per 1000 metres. There was no obvious seasonal pattern in the steepness of this gradient which varied between 8.4°C/1000m (June) and 12.5°C/1000m (October). During cold stable winter nights temperature variation in the lower atmosphere frequently becomes inverted, when Carim is warmer than Parkhead. This was particularly noticeable during the severe cold of January. Unlike maximum temperature, there is usually evidence of seasonality in lapse-rates in minimum temperature. The steepest rates of change with height usually occur during the summer months, and the shallowest during the winter. In 1982, lapse-rate in minimum temperature varied between –6.1°C/1000m (inversion) (January) and 5.0°C/1000m (June). Difference in annual mean temperature between Parkhead and Carim was 2.9°C which represents a rate of decrease of 6.5°C per 1000m. This is comparable with values calculated for other paired stations in the British Isles.

Precipitation increases with elevation, which can be seen in the comparison between Carim and Parkhead. Unfortunately, it was not possible to monitor rainfall at Carim during January, but by comparing rainfall totals with Parkhead over the months February to December, it is possible to make a reasonable inform-guess as to the annual fall at the upland station. Using a ratio comparison, the total is of the order of 1570mm, which is 500mm higher than Parkhead. There were many occasions when the Carim site was shrouded in cloud, which yielded small quantities of measured precipitation when Parkhead was apparently rain-free.

Register of Weather Stations

The Department has been undertaking a survey of weather stations in the United Kingdom which are outwith the "official" Meteorological Office network. These are maintained by observers who collect weather information for their own use, as a hobby, as part of school curricula, or in the course of their research. Details of their weather stations have been obtained by publishing requests for information in relevant journals, and by direct contact with Education and Water Authorities. The *REGISTER OF WEATHER STATIONS*, pp 55 £2.75 is published jointly by the University of Stirling and the Royal Meteorological Society, who have financed the project, and is available from the "University of Stirling" Department of Environmental Science.

Urban microclimatology of Stirling

Urban areas develop distinctive microclimates, the best known feature of which is the "urban heat island" where air temperatures exceed those of the rural surroundings by several degrees. The reason for their development lies in the peculiar radiation and heat energy balance characteristics of urban centres, and the leakage of 'artificial' heat from buildings. The feature is best developed in relatively large towns and cities which have populations in excess of 100,000, and where there is an identifiable core of greater building density. In a settlement the size of Stirling, the probability of a marked heat island developing is relatively small because of its small population, the presence of ground height variation in its centre, and its complex urban morphology. Nevertheless, it has been possible to identify nocturnal decreases in air temperature outwards from the King Street area, which have been related to changes in building density. For further information on this ongoing project contact Dr. Ian Moffatt of this department.

Ground-level rainguages

The conventional 0.125m diameter rainguage is subject to many sources of error of which the effect of the airflow around it is the most important. The gauge interrupts the flow of air across the surrounding surface which creates turbulent eddies around the funnel mouth. This diverts smaller raindrops away from the gauge, thereby reducing its catch (Robinson and Rodda 1969). The greater the wind speed, the greater does this loss become.

One solution to the problem has been to bring the gauge orifice down to ground level and to surround it with a suitable splash resisting grid. Comparison between standard and ground-level gauges throughout the UK (Rodda 1969) have revealed that the rainfall catch is increased in the latter. However, the percentage increase is not constant but varies according to wind speed and to the time period over which comparisons are made. During some storms, the ground level gauge may collect 50 per cent more rain water. Increases in annual rainfall totals are, however, much smaller, being less than 5 per cent at lowland sites.

The importance of wind speed is most clearly seen in the effect of surface elevation on this increase. In the windswept hills of mid-Wales above 500m a.s.l. the increase is of the order of 22 per cent, while at 60m in Oxfordshire the figure falls to 3 per cent (Rodda 1969).

During 1982 weekly precipitation totals have been collected in standard and ground-level Met. Office Mk.II gauges at the Carim weather station. Comparison between them reveals not inconsiderable inconsistency in the increased ground-level catch, which varies from –8.0 per cent (i.e. a decrease) to 24.6 per cent. The average increase for rainfalls greater than 1mm was 5.3 per cent.

References

Robinson, A.C. and Rodda, J.C. 1969. Rain, wind and the aerodynamic characteristics of raingauges. *Meteorological Magazine* 98, 111–120.

Rodda J. C. 1969. On more realistic rainfall measurements and their significance for agriculture. The Role of Water in Agriculture, Aberystwyth Symposia in Agricultural Meteorology, number 12.

Forth Estuary Project

This year has seen the publication of the 5th report on inter-tidal microclimate:

Harrison, S. J. and Hizacklea, A.P. 1982. Tidal effect of fog occurrence in the Forth Estuary. Inter-tidal Microclimate Research Project Number 5, University of Stirling. Available for £1 from the University of Stirling, Department of Environmental Science.

Postgraduate Research

The interception characteristics of upland grasses, by Duncan Ray (now employed by Forestry Commission), for Ph.D.

The hydrological response of hill slopes, by Majid Bagheri, for Ph.D.

Undergraduate dissertations

The frost hollow effect in the Forth valley, by Rae Wallace, 1982.

Radiation levels and temperature variation under a forest canopy, by Robin Sheehan.

Air temperature under contrasting woodland canopies, by Alma Clark.

	Mean Maximum °C	Diff. from Average	Highest Maximum	Lowest Maximum	Mean Minimum °C	Diff. from Average	Highest Minimum	Lowest Minimum	Mean °C	No. of Days <0°C	Mean Earth Temp. °C
January	4.8	−1.0	12.2	−8.4	−2.7	−2.9	8.3	−17.2	0.9	17	–
February	7.6	+1.2	11.7	3.2	0.8	0	5.5	−5.5	4.2	12	(2.6)
March	9.3	+0.6	15.4	4.7	0.3	−1.3	4.3	−3.0	4.8	15	4.3
April	13.1	+1.3	18.7	7.6	2.9	−0.2	6.5	−1.8	8.0	6	8.2
May	15.4	+0.3	23.3	8.3	4.8	−0.2	11.5	−1.5	10.1	3	11.6
June	16.9	−0.5	28.6	12.0	9.8	+1.7	13.0	4.3	13.3	0	15.1
July	(20.5)	+0.8	(25.4)	(14.9)	11.1	+0.5	15.2	8.1	(16.1)	0	17.1
August	18.4	−0.4	26.4	13.5	10.5	+0.5	16.7	4.4	14.4	0	16.2
September	15.7	−0.4	22.3	10.4	8.6	+0.2	15.0	2.4	12.2	0	13.2
October	12.8	+0.2	16.1	10.1	6.6	+1.0	9.4	−0.3	9.7	1	9.8
November	8.8	0	12.0	3.6	3.1	+0.7	9.4	−4.0	5.9	8	6.5
December	6.2	−0.6	11.0	−0.2	0	−1.1	7.5	−6.4	3.1	14	2.2
YEAR	12.5	+0.2	28.6	−8.4	4.7	0	16.7	−17.2	8.6	76	–

TABLE 1 MONTHLY TEMPERATURES (STIRLING, PARKHEAD) 1982

	Mean Maximum °C	Difference Carim – Parkhead	Highest Maximum	Lowest Maximum	Mean Minimum °C	Difference Carim – Parkhead	Highest Minimum	Lowest Minimum	Mean	No. of Days <0°C
January (est. –)	2.5	–2.3	9.0	–9.5	–0.9	+1.8	7.5	–13.2	0.8	13
February	4.5	–3.1	9.0	0.0	0.7	–0.1	6.0	–5.0	2.6	11
March	6.3	–3.0	12.0	1.0	0.9	+0.6	6.0	–3.0	3.6	12
April	9.6	–3.5	16.5	3.0	2.5	–0.4	7.0	–2.0	6.0	8
May	12.5	–2.9	20.5	5.5	4.2	–0.6	9.5	–2.0	8.4	5
June	14.4	–2.5	26.0	9.0	8.3	–1.5	12.5	4.0	11.4	0
July	17.5	–3.0	23.0	12.0	10.1	–1.0	13.5	7.0	13.8	0
August	15.3	–3.1	23.5	10.0	9.4	–1.1	15.5	5.0	12.4	0
September	12.6	–3.1	18.5	7.0	7.1	–1.5	12.5	2.0	8.9	0
October	9.1	–3.7	12.5	6.5	5.1	–1.5	7.5	0.0	7.1	1
November	6.0	–2.8	10.0	0.5	1.9	–1.2	7.0	–2.5	4.0	9
December	3.5	–2.7	8.3	–1.5	–0.2	–0.2	5.5	–5.5	1.6	18
YEAR	9.5	–3.0	26.0	–9.5	4.1	–0.6	15.5	–13.2	6.7	77

TABLE 2 MONTHLY TEMPERATURES (OCHIL, CARIM) 1982

			Greatest fall in 24 hrs.		Number of Days			
	Total Precipitation (mm)	Percentage of average	Amount (mm)	Date	Precipitation Recorded	0.2mm or more	1.0mm or more	5.0mm or more
January	68.0	71	18.6	2nd	16	16	10	4
February	64.8	96	12.9	28th	20	19	15	4
March	121.7	153	23.4	11th	19	19	17	8
April	28.7	78	8.9	7th	8	8	6	2
May	74.4	130	28.3	2nd	16	15	11	5
June	63.2	118	17.3	27th	10	10	9	5
July	18.8	33	6.6	14th	10	10	4	1
August	118.3	190	28.8	5th	23	22	18	7
September	123.5	142	25.5	4th	21	21	18	7
October	110.2	129	21.8	30th	21	20	17	8
November	141.6	137	21.5	5th	22	21	19	14
December	137.3	156	30.2	7th	21	20	15	9
YEAR	1070.5	122	30.2	7th Dec.	207	201	159	74

TABLE 3 MONTHLY PRECIPITATION (STIRLING, PARKHEAD) 1982

	Total Precipitation (mm)	Greatest fall in 24 hrs.		Number of Days		
		Amount (mm)	Date	0.5mm or more	1.0mm or more	5.0mm or more
January	Rainguage not operational					
February	109.5	19.0	28th	22	19	8
March	180.5	27.5	2nd	19	18	11
April	36.5	7.5	4th	9	8	4
May	99.5	40.0	2nd	19	16	5
June	74.9	24.0	11th	13	10	6
July	29.5	9.0	14th	14	9	2
August	187.0	55.5	5th	25	23	11
September (est.)	208.7	33.5	27th	21	18	15
October	175.5	30.5	17th	27	23	12
November	172.0	28.0	5th	22	19	14
December	196.5	39.0	31st	24	20	10

TABLE 4 MONTHLY PRECIPITATION (OCHIL, CARIM) 1982

	Maximum Temperature °C	Minimum Temperature °C	Number of Days <0°C	Earth Temperature (0.3m) (0900 GMT)	Total Precipitation (mm)	Number of Days with Precipitation
January	5.8	0.2	13	3.0	95.6	19
February	6.4	0.8	12	2.8	(67.8)	17
March	8.7	1.6	9	4.4	79.8	18
April	11.8	3.1	5	7.7	37.0	11
May	15.1	5.0	2	11.4	57.4	15
June	17.4	8.1	0	14.5	53.5	14
July	19.7	10.6	0	16.5	57.0	13
August	18.8	10.0	0	16.3	62.4	15
September	16.1	8.4	0	13.7	87.2	16
October	12.6	5.6	3	10.0	85.3	16
November	8.8	2.4	9	6.1	103.4	19
December	6.8	1.1	12	3.7	88.0	18
YEAR	12.3	4.7	65	9.2	874.4	191

TABLE 5 CLIMATOLOGICAL AVERAGES FOR STIRLING (PARKHEAD) UNIVERSITY OF STIRLING (1971–1982)

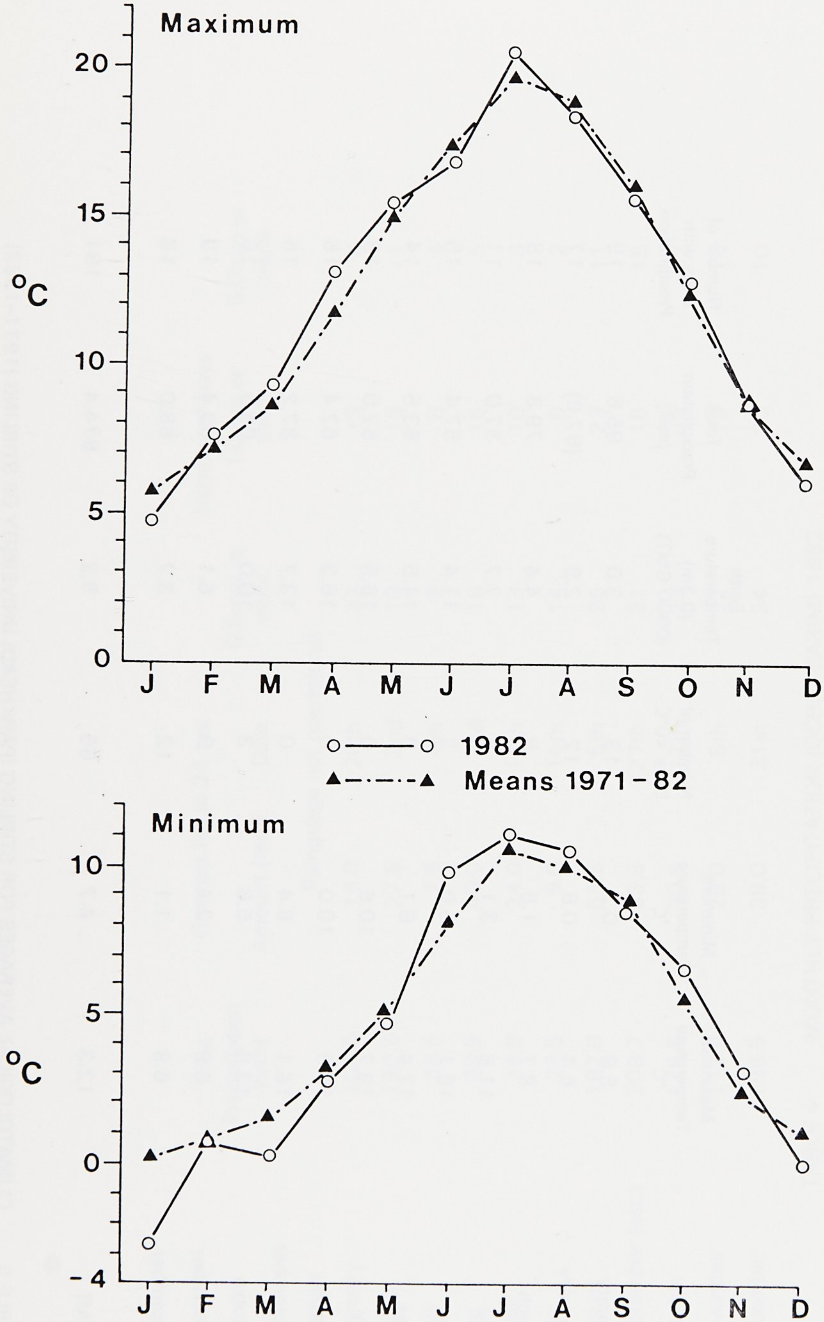

FIGURE 1 AIR TEMPERATURES — PARKHEAD

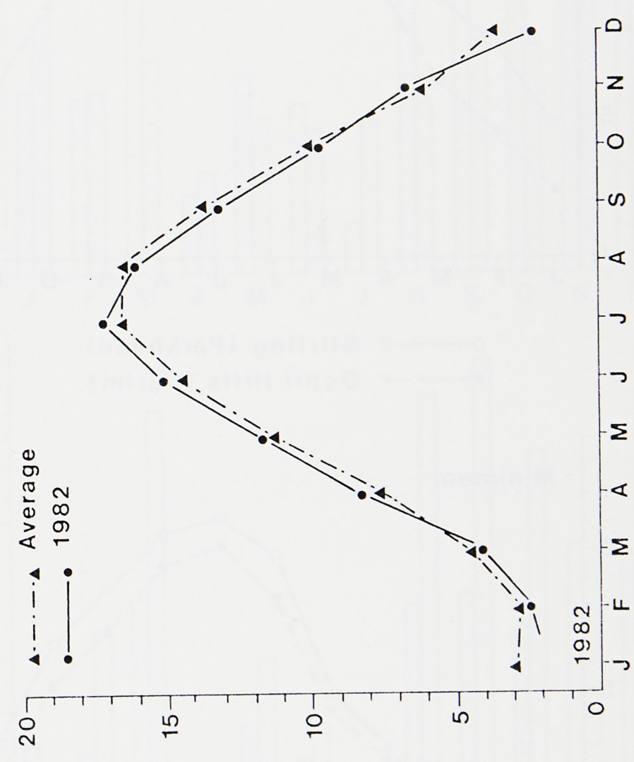

FIGURE 2 EARTH TEMPERATURES — PARKHEAD

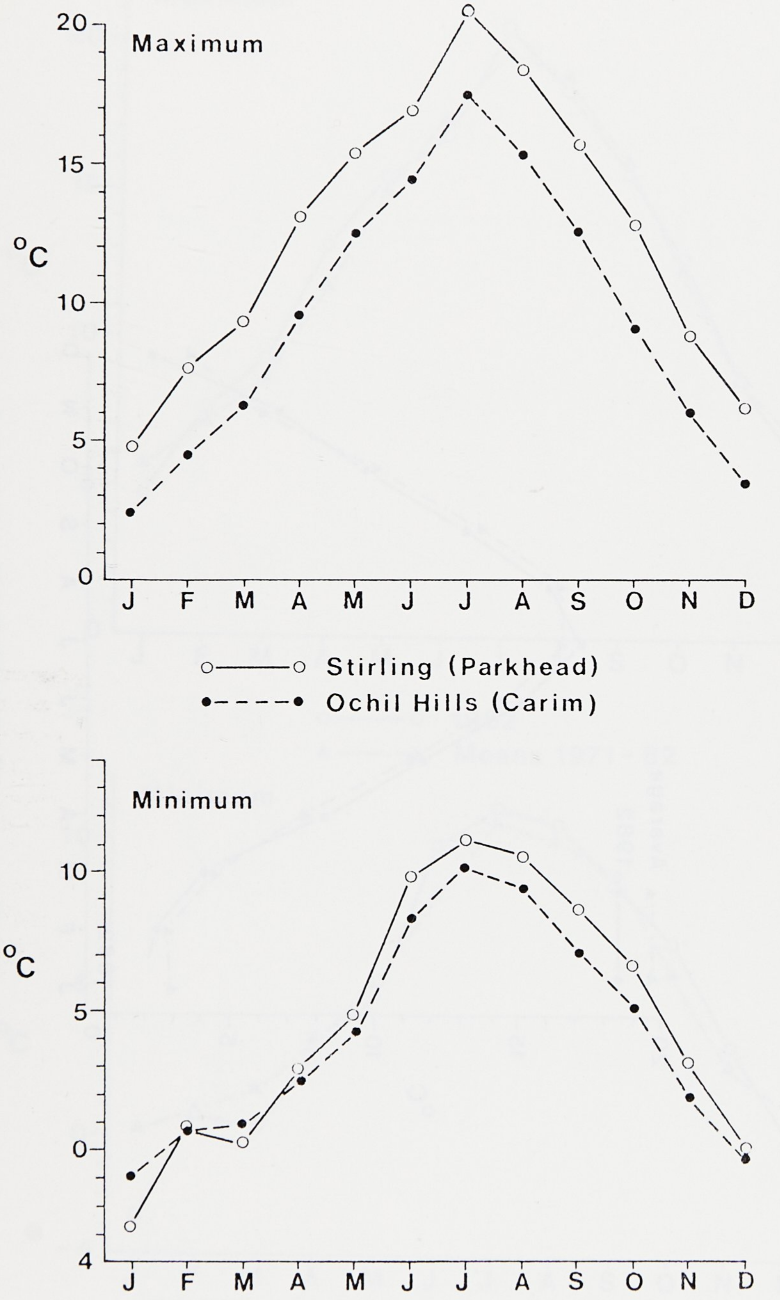

FIGURE 3 TEMPERATURE DIFFERENCES BETWEEN LOWLAND (PARKHEAD) AND UPLAND (CARIM) STATIONS 1982

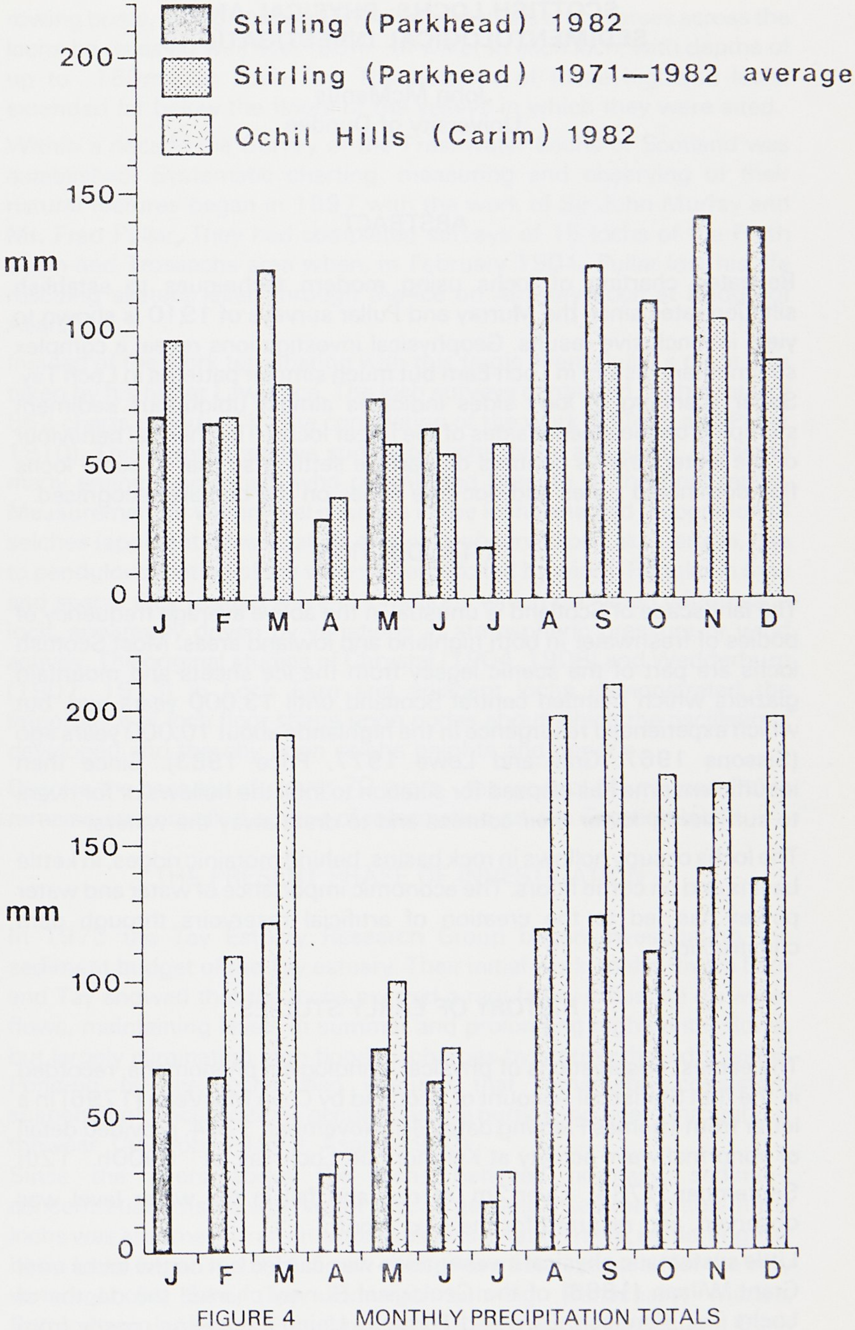

FIGURE 4 MONTHLY PRECIPITATION TOTALS

SCOTTISH LOCHS: PHYSICAL AND SEDIMENTOLOGICAL INVESTIGATIONS

John McManus
University of Dundee

ABSTRACT

Repeated charting of lochs using modern techniques to establish siltation rates since the Murray and Pullar surveys of 1910 is shown to yield inconclusive results. Geophysical investigations reveal a complex sedimentary history in Loch Earn but much simpler patterns in Loch Tay. Sonar scanning of loch sides indicates almost ubiquitous sediment slumping on the steeper sides of the larger lochs. The thermal behaviour of the waters exerts controls on particle settling so that in some lochs floc-dominated zones and floc-free zones on the bed are recognised.

INTRODUCTION

The landscape of Scotland is unusual in the above average frequency of bodies of freshwater in both highland and lowland areas. Most Scottish lochs are part of the scenic legacy from the ice sheets and mountain glaziers which mantled central Scotland until 13,000 years ago, but which experienced resurgence in the highlands about 10,000 years ago (Sissons 1967, Gray and Lowe 1977, Price 1983). Since then insufficient time has elapsed for siltation to infill the hollows or for rivers to sufficiently lower their courses and to drain away the waters.

The lochs occupy hollows in rock basins, behind morainic ridges, in kettle basins and on corrie floors. The economic importance of water and water power has led to the creation of artificial reservoirs through dam construction.

HISTORY OF EARLY STUDIES

The earliest observations of physical limnological phenomena, recorded in the first Statistical Account of Scotland by Colin MacVean (1796) in a letter from Thomas Fleming dated 4th November, 1784, provided detail of abnormal wave activity at Kenmore on Loch Tay, at 0900h. 12th September, 1784. Over 2m of rise and fall in the water level was observed, and recurred for the next month.

Little systematic physical investigation was carried out on the lochs until Grant Wilson (1888) of the Geological Survey charted the depths of Lochs Tay, Rannoch, Earn and Tummel. Using a lead-line mostly from rowing boats, taking readings at uniform intervals on traverses across the lochs he revealed well over 30m of water in each loch, with depths of up to 160m in Loch Tay. The bottoms of these highland lochs extended far below the floors of the valleys in which they were sited.

Within a decade the Survey of the Freshwater Lochs of Scotland was established. Systematic charting, measuring and observing of their natural features began in 1897 with the work of Sir John Murray and Mr. Fred Pullar. They had completed surveys of 15 lochs of the Forth Basin and Trossachs area when, in February 1901, Pullar lost his life rescuing skaters fallen through the ice on Airthrey Loch at Bridge of Allan.

Instead of the work terminating with this tragic event Pullar's place was taken by his father Lawrence. The loch surveys continued, with a total of 562 charts produced by the completion of the work (Murray and Pullar 1910). This comprehensive survey of lochs, large and small, attracted many eminent scientists who contributed breadth to the final report. Measurement of water level changes in the lochs enabled recognition of seiches (apparent tides in lakes, originally observed on Lake Geneva, due to pendulous motion of the water when excited by wind). Regular in time and space, they formed wave-like motions which oscillated within each loch, apparently driven by variations in atmospheric pressure or wind activity. The original studies of Chrystal (1904, 1908) and Wedderburn (1907, 1913) in Loch Earn and adjacent lochs demonstrated the importance of loch floor shape upon nodes about which the oscillations developed and thereby upon seiche heights and periods.

Despite the passage of over 70 years the work of Murray and Pullar remains an unrivalled source of information on the Scottish lochs.

THE PRESENT PHASE OF INVESTIGATION

In 1973 the Tay Estuary Research Group began investigating the sediment budget of the Tay estuary. Their initial work on the Rivers Earn and Tay showed that the lochs exerted a regulatory influence on water flows, maintaining levels in summer and prolonging high winter flows, but largely eliminating high flood discharges by storing the extra water. Ponding by the lochs also ensured that remarkably consistent suspension concentrations occurred in the outflowing rivers throughout the year (Al-Jabbari 1978, Asaad 1982).

Since the rivers above the lochs behaved normally, sediment concentrations rising with water discharge, active sedimentation in the lochs was assumed. In an attempt to assess siltation rates, recharting Tay basin lochs began in 1974. Fresh charts have been prepared for the very varied Lochs Earn, Tay, Tummel, Lubnaig, Benachally, Marlee, Butterstone, Lintrathen, Lindores and Backwater (McManus and Duck 1984).

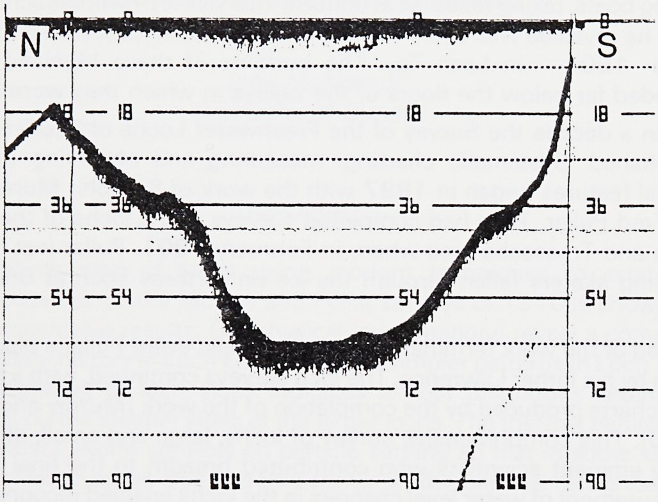

Figure 1(a) Echogram across the western end of Loch Earn towards the mouth of the Ample Burn (S end).

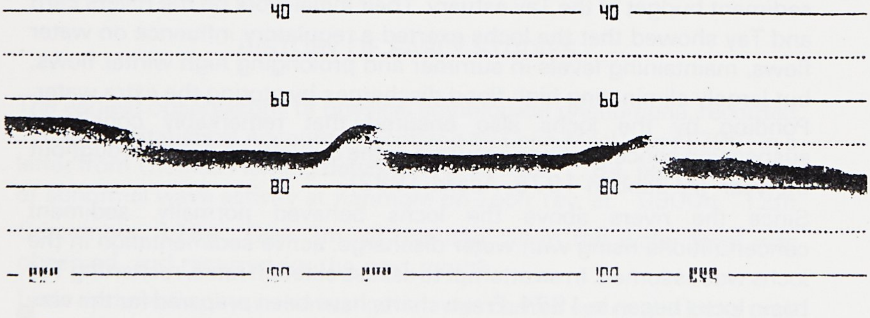

Figure 1(b) Echogram along the deep floor of the centre of Loch Earn, showing flat areas with intervening ridges.

Bathymetric surveying techniques have changed substantially since the days of Murray and Pullar. Electronic echo-sounders provide continuous traces of the bed beneath the survey vessel, radio-position fixing enables the echo-sounder to be located geographically to within 2 m, and outboard motors drive the vessels. The speed of surveying is greatly increased so that many additional traverses may be run in each survey.

The resultant charts differ from those of Murray and Pullar in most cases, the variations mainly resulting from precise location of changes of bed slopes. The presence of hitherto unknown steps and areas of level bed are now revealed (Figure 1). Increased traverse density provides more detail on which charts are based.

Although lead lining and echo-sounding are both bed detection methods they use different textural properties for its recognition. The lead line detects a physical resistance to its fall, whereas the echo-sounder seeks an acoustic reflector at the sediment-water interface. In most, but not all cases, these are identical.

In most charts little significant change is detectable. Extensive flat bed areas with very similar depths are recorded, and the 20–30 cm differences may be technique induced, rather than results of siltation (Al-Ansari and McManus 1980). In most lochs the depths are virtually indistinguishable from those of Murray and Pullar (1910). Changes have certainly occurred in some lochs. In Loch Tummel the surface level was raised by 5 m with the building of the Clunie dam. The Queen's View today scarcely resembles that which failed to impress Queen Victoria so many years ago. The loch surface area has increased, extra islands have formed, and the influent river has been drowned. Its flood plain and levees are still detectable by echo sounder (Duck 1982). Entrance levees occur on other lochs, being particularly well displayed in Loch Lubnaig.

While the lead line recognises one surface, the echo-sounder not uncommonly detects textural differences extending several metres below the bed of the loch. By selection of sounders with suitable performance, sedimentary sequences lining the loch floors may be explored. The acoustic texture of the reflections suggests the nature of the materials present.

By means of pinger equipment reflections are obtained of signals penetrating deeply below the loch floor. Beneath the western basin of Loch Earn the flat-lying sequences exceed 20 m and thinner sediments cover the bed to the east. Drape thicknesses decrease rapidly onto the steep loch sides. The underlying tills and bedrocks are identified on the pinger records. In Loch Tay the layered sediments are thin throughout the western basin, thickening irregularly eastwards. The contrast of the sedimentation histories between the thick complexes of Loch Earn and

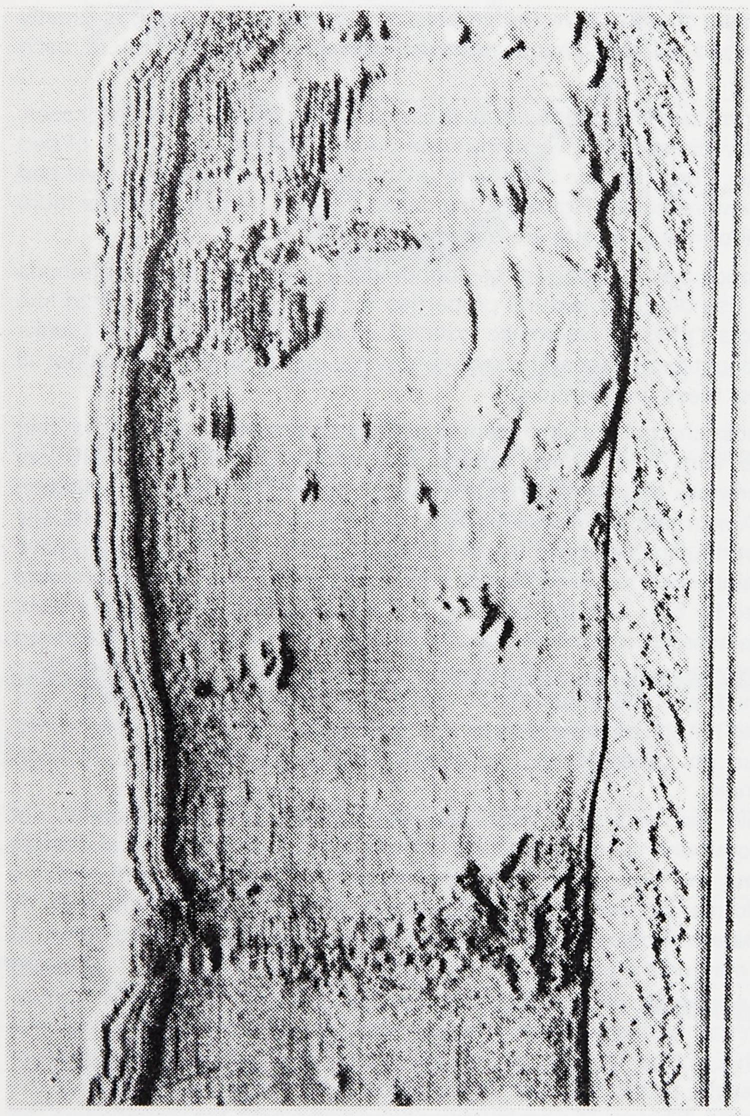

Figure 2 Sonargraph of part of the northern shore of Loch Earn. The multiple lines are from shore-parallel steps; the linear pattern on the left is scour below a stream mouth; curving traces to the right are from mud slides moving down slope.

the thin sequences of Loch Tay is currently under investigation.

Cores of undisturbed sediment from loch floors are consistently obtained only in flat bed areas. Those from loch slopes and wall foot regions often exhibit disturbed layering implying that the sediments have undergone movement since deposition. The concept that sediment settles onto steep slopes, accumulates until the blanket becomes unstable then slides downslope has been long known from the English Lake District, where botanists examining pollen sequences found that 'bad cores' with confused successions characterise slopes and slope foot zones (Holmes 1968).

Sideways scanning sonars provide acoustic images of the slopes showing strong reflections from upstanding features which have 'shadows' behind. Bed structures and surficial slope irregularities are detected with the scanner either at the surface or at controlled depth below the vessel. Records from Lochs Earn, Lubnaig and Tay reveal discontinuous scans extending along the slopes, indicating blister-like structures where sediment masses are slumping under gravity (Figure 2). Present where slopes exceed 7%, they become profilic, often amalgamating on very steep slopes.

In contrast to these, linear scours run down the slopes below drainage culverts and small streams.

Rotational slides analogous to subaerial landslips occur in shallow nearshore zones which are normally characterised by multiple shore-parallel ridges (McManus and Duck 1983). Such ridges are exposed when water level falls during drought conditions and are prominent features of the upper slopes of drawn-down reservoirs.

Although the formation of the sediment slumps is principally gravity controlled, it may be aided by internal seiche waves and also by local seismic activity. A possible link between the Loch Tay fault and swarms of slumps along the steep slopes of the central sector of the loch cannot be discounted solely because the echograms show no detectable recent displacement on the fault. The density of slumping is probably related to the slope steepness. Slumps occur at many levels on the slopes suggesting that movement occurs over the entire surface. At many sites several generations of sliding are present.

The slumped sediments are dominantly muds or silts, but coarser materials also enter the lochs from rivers or through shoreline erosion. In most Scottish rivers only 3–5% of the sediment transported is sufficiently coarse to move along the bed. Rivers entering the quiet loch waters lose their ability to carry sediment so that pebbles and sands are deposited to form river mouth deltas. The remaining suspended matter becomes entrained within the circulating loch waters.

The fine particles, mineral fragments of humic soil debris or organic tissues gradually sink through the water. The settling rates are partly determined by particle size, density and shape, but water viscosity resists settling. Each particle settles independently so that a gradation from coarser heavier particles on the bed near influent rivers and coasts to finer particles in more remote sites is anticipated.

However, in concentrated suspensions particles sinking through the waters may catch up and collide with smaller ones. All have minute electrical charges on their surfaces due to their internal chemistry, ends and faces often having different charge polarity. If the charges are strong enough the particles adhere after collision building aggregates, of mixed size particles, which settle more rapidly than individual particles.

The formation of aggregates or flocs is well known where salts enter water as in estuaries but also occurs where water circulation stimulates interparticulate collisions. Floc-dominated loch floors are soft and offer little resistance to penetration by lead line, grab or driver. Many lochs exhibit floc-dominated reaches but elsewhere less rapid settling and early dewatering yields firmer but still muddy bottoms.

Particle settling in lochs is strongly influenced by the water circulation. In winter the waters are chilled and the densest (4°C) water sinks. Above, the waters achieve uniform temperature. In late spring the surface waters become heated and an upper layer several metres thick develops, with low density warm waters above denser cold water. With the onset of winter thermal layering collapses and the water becomes isothermal again.

Streams entering the lochs may flow into the upper layer, sink through the lower layer, or run along the boundary between the two according to the water temperatures. Thus the sediment distribution, potential flocculation and settling histories of the particles vary seasonally.

Wind also influences loch water circulation. Frictional energy transfer moves the surficial waters creating waves and currents. Waves form and disappear swiftly in fresh waters. They attack shorelines, damage structures, resuspend deposited sediments and carry sand and pebbles along shore. Wave generation in lochs is presently predicted from wind records. In order to test prediction effectiveness on Scottish waters an oceanographic wave-rider buoy was deployed on Loch Earn during 1983/84. The floating sphere with flashing red light moored off St. Fillans and which resembled a fallen satellite actually measured wave heights and periods in summer and winter to aid design of bank protection measures.

Historic changes of sediment input from the rivers may be preserved in loch floor deposits. Variations of soil erosion marking the decline of agricultural activity from the golden years of the Nineteenth Century to low levels during the 1930's, the upsurge in tillage of marginal lands during the 1939–45 war and the post-war modifications have all left their evidence in the sequences of grains deposited in lochs and reservoirs. The greater the area devoted to bare-earth or 'cash crops' the coarser the materials carried into the basins, linking recent detailed estimation of the impact of man on his landscape through the acceleration of soil erosion during the last few hundred years.

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BOOK REVIEW

DISCOVER LOTHIAN BEACHES (A Guide to their Natural History), Diane Craik and Kathleen Anderson, Napier College, Edinburgh. 1984. £1.

This spiral bound booklet has been produced by two of the staff of Napier College's Department of Biological Science, in association with their Department of Print Media, Publishing and Communication. It describes the shores of the Lothian Region, from Society shore (near South Queensferry) past Edinburgh and North Berwick, to Dunbar in the east. For each of nine chosen locations (Society, Cramond, Fisherrow, Fernyness, Aberlady, Gullane, Yellowcraig, Seacliff and John Muir Country Park), the authors give guidance on access, parking, toilets etc., followed by detailed descriptions of the fauna and flora which may be found on each beach. The authors give especially complete information on the seaweeds, and rocky-shore animals which may be found, and supplement this with marginal drawings. A last chapter is devoted to possible projects. There is an index and book list.

The book appears to be intended primarily for school-teachers, and I am sure will be a useful guide for both them, and others conducting parties onto the shore. The authors rightly stress that more detailed identification guides will be required for any thorough examination of life on the shore. Agreeing with that caveat, I am sure that this booklet will prove to be of considerable use to those who visit the shores of the Forth.

D. S. McLusky

THE FOOD OF THE BULLHEAD (*COTTUS GOBIO* L.) IN THE GOGAR BURN, LOTHIAN, SCOTLAND

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Institute of Terrestrial Ecology

SUMMARY

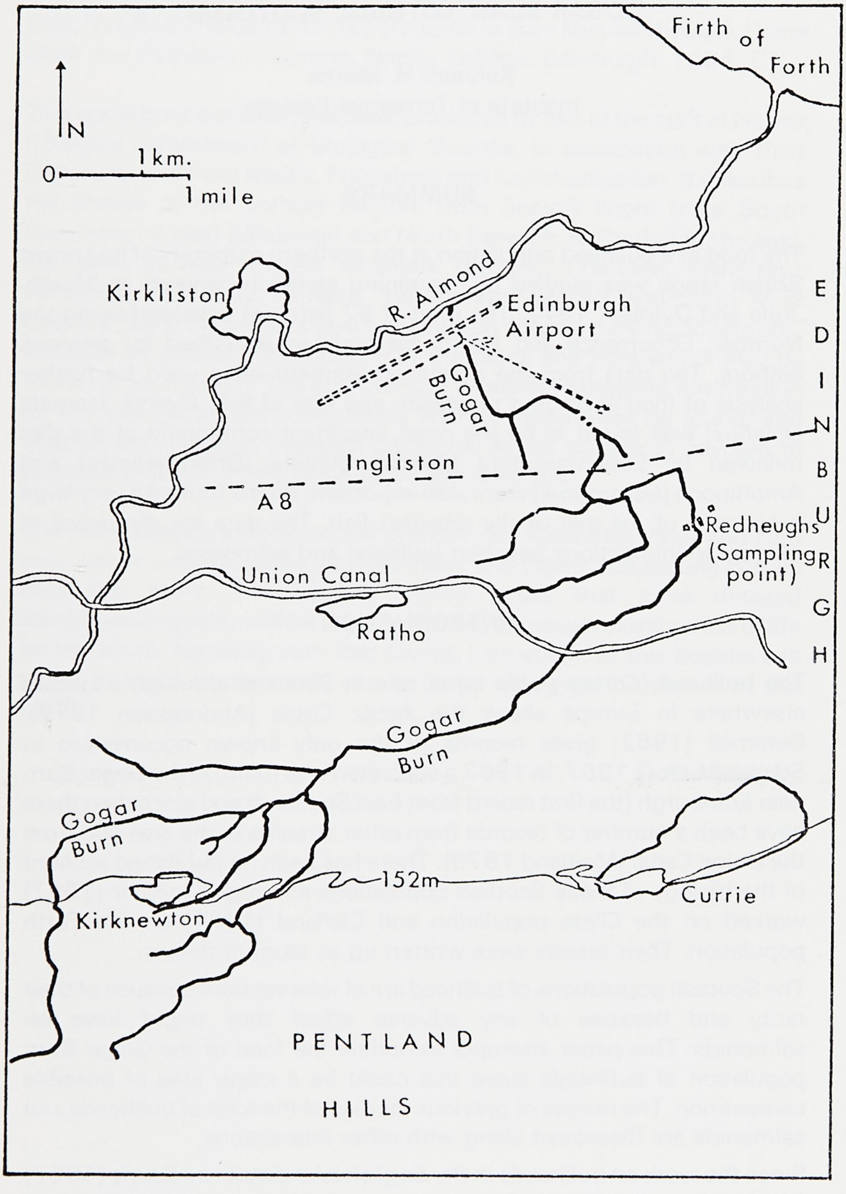
The food of a bullhead population at the northern extremity of its known British range was studied by examining stomach contents in March, June and October, 1977. The food of 97 fish was assessed using the Number, Occurrence and Points methods as described by previous authors. The data from the points assessment were used for further analysis of food according to season and size of fish. Overall, Isopoda (*Asellus*) was found to be the most important component of the diet followed by Ephemeroptera (*Baetis*). Diptera (Orthocladiinae) and Amphipoda (*Gammarus*) were also important. *Baetis* formed a very large proportion of the diet of the smallest fish. The data are discussed in relation to interactions between bullhead and salmonids.

INTRODUCTION

The bullhead (*Cottus gobio* L.) is rare in Scotland although it occurs elsewhere in Europe above the Arctic Circle (Andreasson 1972). Gemmell (1962) gives records of the only known occurrences in Scotland before 1967. In 1967 a specimen was found in the Gogar Burn near Edinburgh (the first record from East Scotland) and since then there have been a number of records from other streams in the area and from the Union Canal (Maitland 1979). There has been no published account of the biology of these Scottish populations although McAleer (1967) worked on the Clyde population and Clelland (1971) on the Forth population. Their results were written up as student theses.

The Scottish populations of bullhead are of interest both because of their rarity and because of any adverse effect they might have on salmonids. This paper attempts to outline the food of the Gogar Burn population of bullheads since this could be a major area of possible competition. The results of previous studies of the food of bullheads and salmonids are discussed along with other interactions.

Since the work on bullheads in the English lake district by Smyly (1957) there has been a number of studies which included accounts of bullhead diet in England. Crisp (1963) studied the food of brown trout, *Salmo trutta* L. and *Cottus gobio* in four becks of the upper Tees system in Westmorland. Mann and Orr (1969) studied the food of fish



Map of the Gogar Burn
A broken line indicates that the burn has been piped

communities (including *C. gobio*) in the Bere Stream in Dorset. Crisp *et al* (1978) studied the effects of impoundment on the food of *C. gobio*, *S. trutta* and the minnow *Phoxinus phoxinus* (L.) at Cow Green, Upper Teesdale.

Outwith the British Isles: Andreasson (1971) gave an account of the food of *C. gobio* in Trydeo, southern Sweden and Straskraba *et al* (1966) looked at food competition between the carpathian sculpin, *Cottus poecilopus* Heckel (a close relative of *C. gobio*), *P. phoxinus* and *S. trutta* in the Moravka stream in Czechoslovakia.

DESCRIPTION OF SITE

The Gogar Burn, a tributary of the River Almond, rises in the Pentland Hills at an altitude of about 274 metres. It flows northwards through farmland on the western edge of Edinburgh to join the River Almond near Edinburgh Airport, about 5 km upstream of the Forth Estuary. The underlying geology is of Calciferous Sandstone and Carboniferous Limestone. The average and range in water quality of the Gogar Burn in 1977 is shown in Table 1.

TABLE 1 Water quality information from the Forth River Purification Board Annual Report for the Gogar Burn, 1977.

	MEAN	RANGE		MEAN	RANGE
Mean Daily Flow 1/s	764		Ammonia Nitrogen mg/1	0.6	0.1–1.3
Temperature °C	10.1	3.0–17.5	Nitrate Nitrogen mg/1	7.2	1.7–12.5
pH Value	7.8	7.2–8.4	Ortho-Phosphate (as P) mg/1	0.18	0.03–0.60
Electrical Conductivity uS/cm	553	420–710	B.O.D. (5 days at 20°C) mg/1	3.4	1.2–7.1
Suspended solids mg/1	18	3–102	Chloride mg/1	40	25–67
			Dissolved oxygen % saturation	96	82–114

At the point where bullhead samples were taken (Grid Ref. 36179718, Alt. 46 m) the Gogar Burn runs between low grassy banks through a field used, at the time of sampling, for grazing horses. A bridge about 50 m upstream carried a farm access road across the stream. The substrate of the section sampled consisted of bedrock, stones and gravel with some silt near the banks. It was mainly riffle with some wadeable pools. A few bushes and small trees overhung the stream. The other fish species present in this stretch of stream were three-spined stickleback *(Gasterosteus aculeatus* L.) and stone loach *(Noemacheilus barbatulus* (L)).

METHODS

Samples of bullhead were collected by electrofishing in March, June and October, 1977. Before sampling, a section of the stream was isolated by placing stop-nets across its breadth about 54 metres apart. The section of stream between the stop-nets was divided visually into Upper, Middle and Lower sections, each of which were shocked three times. In order to reduce disturbance of the bullhead territorial distribution, the fish from each section were counted and measured for length separately, a few retained and the rest released in their own section of stream. The sample of fish retained from within the stop-nets was supplemented by fish caught outside the sampling stretch to make up a sample of at least 30 fish. This sample was brought back to the laboratory where each fish was measured for length and weight, sexed and the stomach removed and placed entire in 70% alcohol.

At a later date each stomach was opened under a binocular dissecting microscope and a visual assessment made of percentage fullness. Each stomach was awarded a number of points between 0 (completely empty) and 20 (completely full and slightly distended). The contents were identified to species and counted, where possible, then awarded a number of points according to a subjective assessment of the volume of stomach occupied by each item. The number of fish in which each food item occurred was also calculated. The number, points and occurrence methods of assessment used here were described by Hynes (1950) who found the points method as satisfactory as any. In a comparison of methods of food analyses based on Hynes's review Windell (1968) concluded that "While the methods available differ considerably, in most studies substantially the same comparative results are obtained with all of them". In addition to food assessment, length/frequency and sex data were calculated for comparison with feeding. Due to the difficulty of sexing a number of the fish (especially the immature ones) no comparisons of length or food by sex was made. During October 1976 a number of timed kick samples were taken from the benthos of the Gogar Burn within the known bullhead range. The nearest sample to the bullhead diet study area was about 1.5 km upstream and these results were used for comparision with the bullhead stomach contents.

RESULTS

Figure 1 The relative quantities of each food type as assessed by the Number, Occurrence and Points methods for all the bullhead stomachs examined in the year (n = 97).

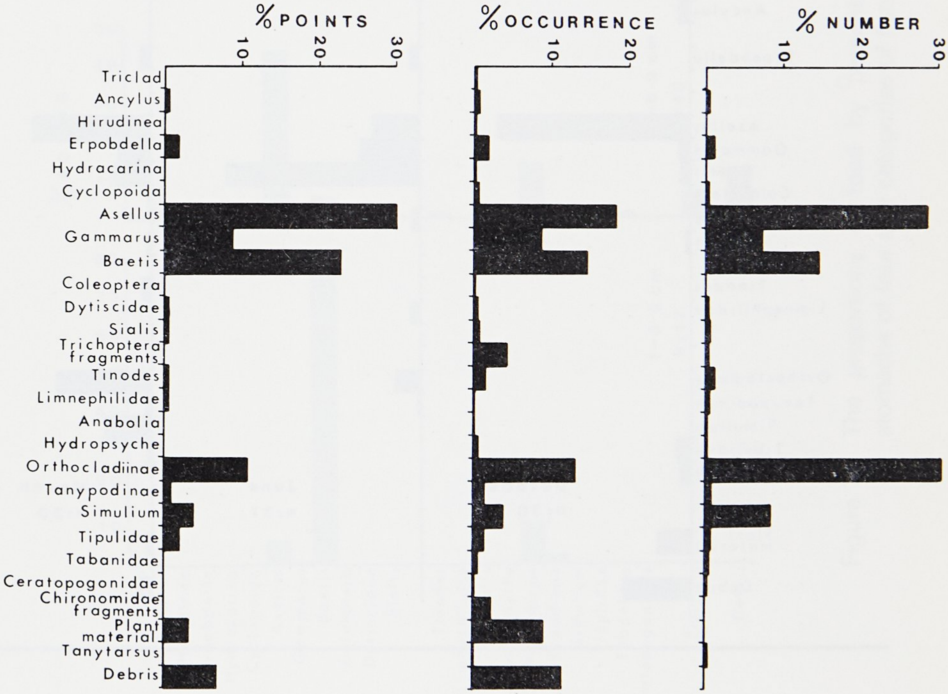


Figure 1 shows the relative quantities of each food type as assessed by the Number, Occurrence and Points methods for all the bullhead stomachs examined in the year. The dominant food type by percentage numbers is Orthocladiinae larvae (Diptera) followed closely by *Asellus* (Malacostraca). The percentage occurrence and percentage points assessments both have *Asellus* dominant followed by *Baetis* nymphs (Ephemeroptera) and Orthocladiinae.

Figure 2 The percentage points by food types for each of the three months sampled.

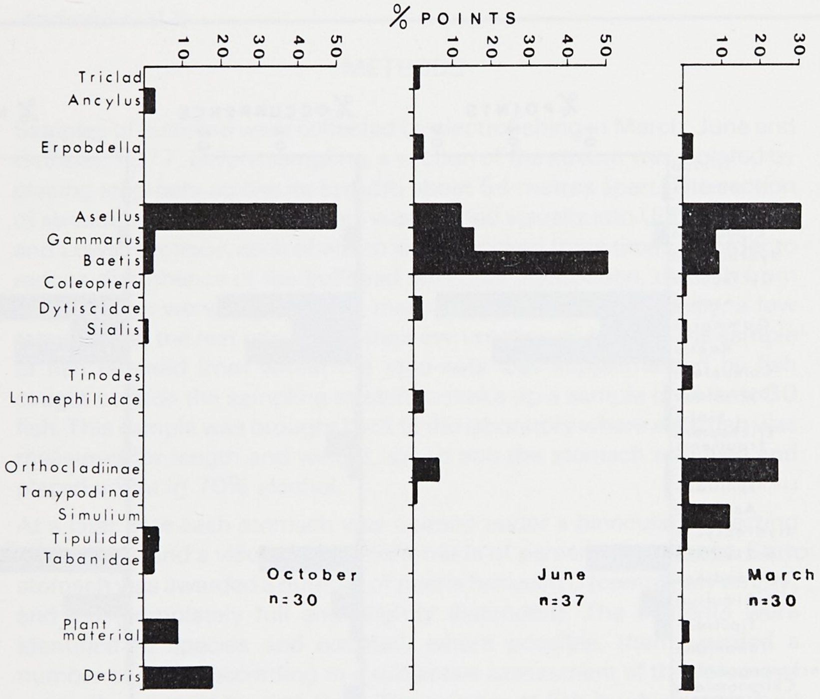


Figure 2 shows the percentage points by food types for each of the three months sampled. In March, *Asellus* was the dominant food type closely followed by Orthocladiinae. In June, *Baetis* was dominant with *Gammarus* (Malacostraca) and *Asellus*, much less important. In October, *Asellus* was almost the sole component of the bullhead diet; there was also much more plant material and debris than in previous samples.

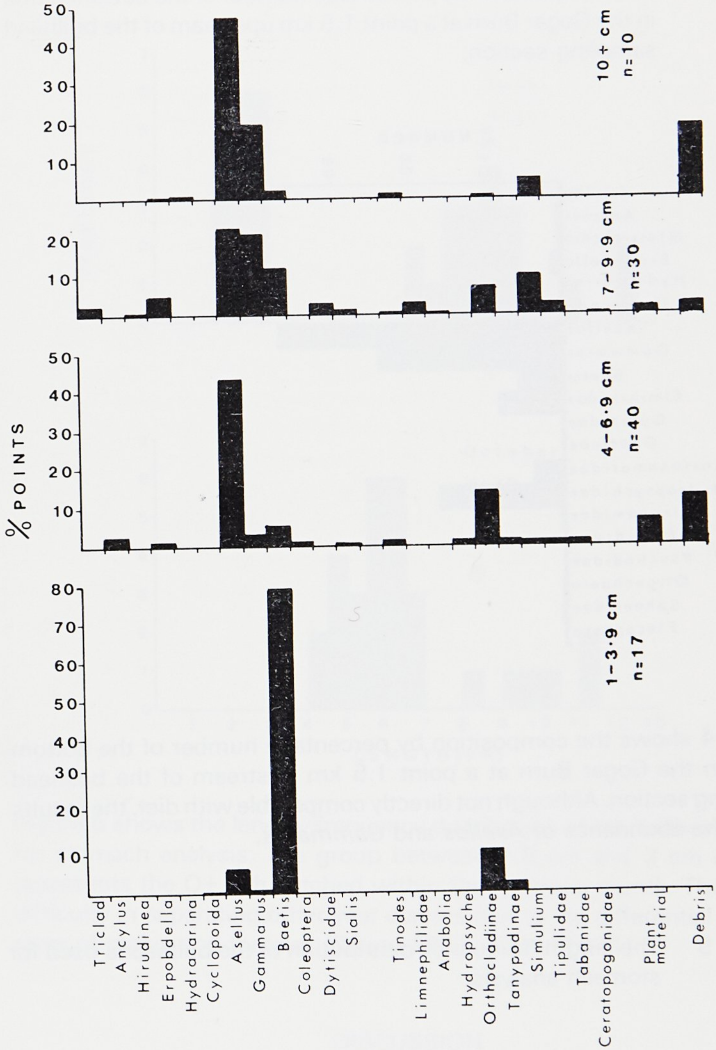


Figure 3 The proportions of food by percentage points in the stomachs of four size categories of fish.

Figure 3 shows the proportions of food by percentage points in the stomachs of four size categories of fish. The most outstanding feature is the importance of *Baetis* in the diet of the smallest fish. In general, Orthocladiinae and *Baetis* increased in importance in the diet of small fish. *Gammarus* was more important for larger fish. *Asellus* was important in the diet of all fish but was least important for the smallest fish. Variety of diet tended to change with size: the largest and smallest fish having the least varied diet.

Figure 4 The composition by percentage number of the bottom fauna in the Gogar Burn at a point 1.5 km upstream of the bullhead sampling section.

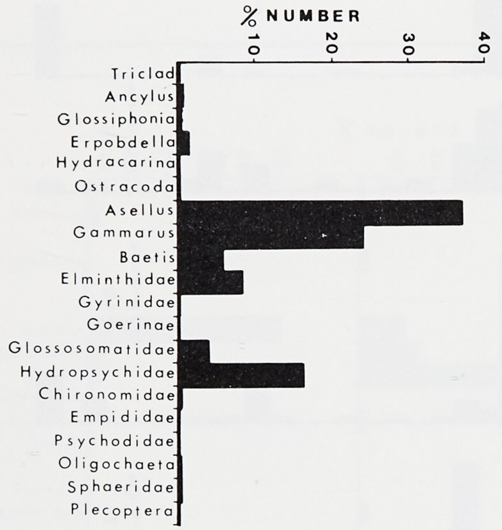
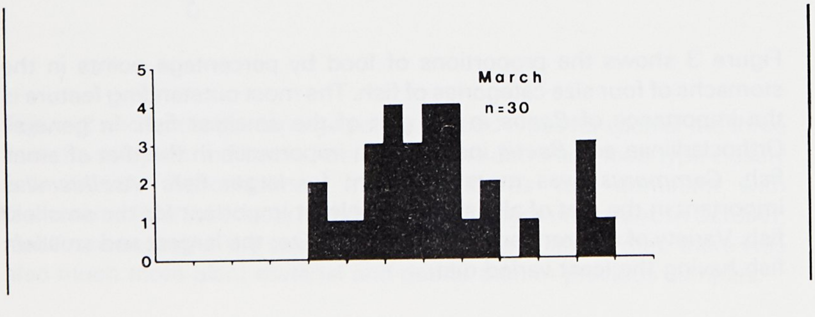


Figure 4 shows the composition by percentage number of the bottom fauna in the Gogar Burn at a point 1.5 km upstream of the bullhead sampling section. Although not directly comparable with diet, the results show the abundance of *Asellus* and *Gammarus*.

Figure 5 The length/frequency distribution of the bullheads used for stomach analysis.



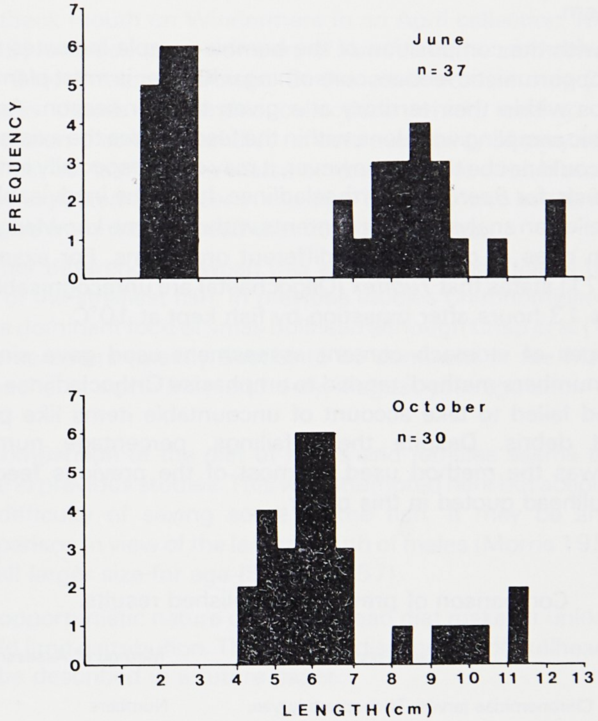


Figure 5 shows the length/frequency distribution of the bullheads used for stomach analysis. The group between 1.5 cm and 3 cm in June represents the O+ fish hatched within the previous month. There was difficulty in separating other year classes due to the differential growth rates of males and females (Smyly 1957, Mann 1971).

DISCUSSION

Asellus was clearly a very important component of the diet of Bullhead in the Gogar Burn in 1977. It was important at all times of the year and was the main food item for all but the smallest fish, in which there was a marked preference for *Baetis* nymphs. The other main components of the diet were also benthic invertebrates, notably Orthocladiinae and *Simulium* (Diptera) larvae and *Gammarus*. There was no evidence of the consumption of terrestrial or aerial drift organisms although some plant material and 'debris' consisting of sand particles and detritus were found in the stomachs of medium and larger sized fish especially in October. This material may be ingested accidentally when the fish seizes a prey organism.

Comparison with the composition of the benthic sample indicates that bullhead are opportunistic feeders consuming whatever is most plentiful in the benthos within their territory at a given time or season. As no detailed benthic sampling was done within the feeding area the existence of selectivity could not be tested; however, it may exist, especially among the smallest fish, for *Baetis* and Orthocladiinae. It may be inadvisable to make too detailed an analysis of gut contents without some knowledge of differences in rates of digestion of different organisms. For example Western (1971) states that *Tubifex* (Oligochaeta) are unrecognisable in bullhead guts 13 hours after ingestion by fish kept at 10°C.

The three types of stomach content assessment used gave similar results. The 'numbers method' tended to emphasise Orthocladiinae and *Simulium* and failed to take account of uncountable items like plant material and debris. Despite these failings, percentage number assessment was the method used by most of the previous feeding studies on bullhead quoted in this paper.

TABLE 2. Comparison of previously published results.

Author(s)	Dominant Food Types	Method of Assessment
Andreasson (1971)	Chironomidae larvae, Trichoptera larvae, *Gammarus* and Ephemeroptera nymphs	Numbers
Crisp (1963)	Chironomidae larvae, Plecoptera nymphs, Trichoptera and Ephemeroptera	Occurrence
Crisp *et al* (1978)	Chironomidae, Plecoptera, Trichoptera and Ephemeroptera	Numbers
Mann and Orr (1969)	Chironomidae, Ephemeroptera and *Gammarus*	Numbers
Smyly (1957)	Ephemeroptera, Plecoptera, Trichoptera and *Gammarus*	Percentage Fullness
Straskraba *et al* (1966)	Chironomidae, Plecoptera, Trichoptera	Numbers

The essentially benthic character of the bullhead diet in the Gogar Burn is in agreement with the findings of other workers (Table 2). However, none of the previous studies found *Asellus* to be such an important component of the diet although Smyly (1957) mentions it as occasionally eaten and found it to be the main component of diet at Troutbeck mouth on Windermere in an April collection. Mann and Orr (1969) recorded small numbers of *Asellus* in the stomachs of bullhead from Bere Stream in Dorset. Of the other studies only Crisp (1963) includes details of benthic collections which tend to support the impression that bullhead diet reflects availability of prey species in the benthos: as *Asellus* was scarce or absent in the stream studied it could not be expected to appear in the diet. This may also be the reason for its absence from the bullhead diet in other studies.

Another difference between this and previous studies is the dominant food of the smallest fish. In previous studies Chironomidae were stated as the dominant food of small bullhead although Crisp *et al* (1978) found Ephemeroptera (mainly *Baetis*) to be dominant in the Maize Beck fry stomachs in April/May and July/August pre-regulation of the River Tees.

No comparison of the diet of males and females seems to have been made in previous studies. This was attempted here but abandoned due to the difficulty of sexing some of the fish. It may be an interesting comparison in view of the larger mouth of males (Morris 1954) and their overall larger size for age (Smyly 1957).

The opportunistic nature of the bullhead diet makes it unlikely that food would limit distribution. The detailed distribution of bullhead in Scotland will be described in a future paper.

INTERACTIONS BETWEEN BULLHEAD AND SALMONIDS

Food

Andreasson (1971) found the food of small trout and large sculpin (*C. gobio*) to be similar in spring but different in summer and autumn. He raised the question of whether the same diet necessarily indicates competition between two species.

Crisp (1963) found that larger trout fed on bullheads. Bullhead and trout fed on similar benthic invertebrates but trout supplemented their diet with large amounts of surface foods of both aquatic and terrestrial origin.

Mann and Orr (1969) found that in Bere Stream, trout have a more varied diet than other fish and make sole use of surface organisms while bullhead diet is benthic. Atlantic salmon, *Salmo salar* L., make use of a very few food types. The main food items were found to be similar for salmon, trout, bullhead, stickleback and minnow.

Straskraba *et al* (1966) found nearly the same groups of food organisms were eaten by trout, minnow and carpathian sculpin (*Cottus poecilopus*) but were represented by different invertebrate species in each species of fish so there was no evidence for strong competition.

Smyly (1957) concluded that bullhead rarely eat salmonid eggs but could possibly prey on alevins due to the habit of feeding on moving prey.

The results of other workers would suggest, therefore, that, although *Cottus gobio, Salmo trutta* and *Salmo salar* L. tend to consume the same major food types, there is no clear evidence for competition. However, Maitland (1965) in his study of the food of a community of fishes which included salmon and trout, discussed the fact that reduction of even partial competition could increase the biomass of salmon. It may be reasonable to suggest that addition of bullhead to a salmon/trout stream might reduce the biomass, especially of salmon since trout have a compensatory consumption of terrestrial and aquatic drift to supplement benthic organisms.

Behaviour

In addition to the effects of food competition and possible predation on alevins, bullhead territorial behaviour might also affect salmonids. Smyly (1957) described bullhead as stationary and solitary, living alone under a stone which they treat as feeding and breeding territory such that they will drive off any other fish which comes near. He described the effect of this on stone loach which also live under stones so that, in the River Brathay at Purdom's Dub, where one species is abundant the other is usually scarce. Morris (1954) described the aggressiveness of male bullhead in spring toward any object which moves near its nest. This territorial behaviour might affect small salmonids which tend to hold a fairly static feeding position, particularly salmon because of their tendency to lie on the substratum (Maitland 1965).

In the Gogar Burn, bullhead and salmonids were never found together. Although trout and bullheads were caught together in small numbers in the Murrayburn and the Water of Leith, both of these streams were artificially stocked with trout. The scarcity of salmonids in the Gogar Burn may have contributed to the successful colonisation of bullhead or, alternatively, the spread and increase in numbers of bullhead may have inhibited salmonid production. The Gogar Burn would be unsuitable for testing either of these possibilities.

More detailed work must be done before the effects of bullhead on salmonids can be stated with any certainty. In the meantime it would clearly be unwise to introduce bullhead to any other salmonid streams in Scotland.

ACKNOWLEDGEMENTS

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FORTH AREA BIRD REPORT (CLACKS, STIRLING, SOUTHWEST PERTH) 1982

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University of Stirling

This report covers, as in previous years, the general area of the Central Region (the Districts of Stirling, Clackmannan and Falkirk) excluding Loch Lomondside and the Killin area. This area has been chosen to get maximum compatability between the modern administrative districts, a natural geographical unit and the areas worked by birdwatchers who belong to or are in contact with the local Stirling branch of the Scottish Ornithologists Club. A map of the area can be got from the editor if anyone is doubtful about borderline records.

The early winter in 1982 was marked by severe cold in the second week of January and this had an effect on the distribution of wildfowl. The rest of the winter was relatively mild and wet and of small breeding birds only the Wren was noticeably decreased. Spring and early summer were dry but from August to the end of the year there was a great deal of rain with September and October being stormy and only a brief cold spell in mid November.

Stonechats seem to have become extinct as a breeding species, there was little in the way of special note except the reappearance of Bean Geese in Carron Valley and a White Stork in May.

Due to lack of time in preparing this report it has not been possible to fully assimilate all records submitted and the choice presented here may well be inconsistent between species and previous reports. Quite a number of common species are not mentioned here simply because the existing records give no basis for sensible or reliable comment. I apologise for omissions of all kinds but can see little prospect of any great improvement under present circumstances. I have in places changed the locality from a very specific place which would be unknown to most readers to a more familiar one whilst the term 'Grangemouth' refers to the area from Skinflats to Kinneil except where it was convenient or important to make distinctions.

An asterisk indicates that all the records for a species have been quoted whilst the sections headed by C, S and SWP refer to notes for Clackmannan, Stirlingshire and southwest Perth respectively.

The following observers are referred to by initials in the report:

W.R. Brackenridge, D.M. Bryant, R.L. Calder, D.L. Clugston, G.M. Cresswell, N. Faulkner, J. Gearing, Carron Valley Group*, C.J. Henty, G. Jones, D.H. McEwen, I. McGowan, D. Matthews,

J. Mitchell, A. Robertson-Durham, R. Shand, D. Thorogood.

*includes J.G. Conner, D. McEwen, I.P. Gibson, J. Simpson, A.D. Wood, A. Young, B. Zonfrillo.

SYSTEMATIC LIST

*RED-THROATED DIVER
- S 1 at Skinflats on 14th March and 9th September (GMC)

GREAT CRESTED GREBE
- S at Grangemouth, 103 on 24th January and 107 on 17th February, 25 on 10th August increasing to 246 on 13th December (DMB CVG DT).
  At Carron Valley Reservoir until 13th November, no breeding proved — water level low (CVG)
- SWP 2 pairs at Lake of Menteith but no proved breeding (WRB)

*FULMAR
- S 1 at Skinflats on 14th and 4 on 21st May, 2 on 5th September (DMB GMC NRF)

*MANX SHEARWATER
- S 1 at Skinflats on 11th September (GMC)

*GANNET
- S 16 at Grangemouth on 4th and 4 on 14th September (DMB GMC). An exhausted immature at Touch on 5th September (D. Holmes, per JM)

CORMORANT
- C 81 at Alloa Inch on 7th February (WRB)
- S 75 at Skinflats on 7th February, 42 at Stirling on 14th January and 14 at Carron Valley Reservoir on 14th March (JG CVG)
- SWP max. 8 (in tree) at Lake of Menteith on 18th April, also at L. Ard, L. Katrine, L. Voil and L. Lubnaig in February and December (WRB DMcE)

*NIGHT HERON
- SWP 1 at Barbush gravel pit on 20th May (GJ)

GREY HERON
- S 19 at Skinflats on 20th September and 16 at Carron Valley Reservoir on 13th November (GMC CVG)

*WHITE STORK
- SWP 1 at Menteith on 31st May, following plough (K. Graham)

MUTE SWAN
- C 33 at Gartmorn Dam on 28th November; some oiling seen at Cambus (WRB)
- S broods of 7 at Airthrey and 8 at Cocksburn (WRB CJH)
- SWP broods of 9 at L. Watston and 5 at L. Lubnaig (WRB)

*BEWICK'S SWAN
- SWP 4 adults at Thornhill on 17th and 19th December (DT JG)

WHOOPER SWAN
- C max. 56 at Alva on 29th November and 40 on 29th December, 89 at Gartmorn Dam on 27th November (IMG CJH)
- S 5 SE over Pendreich on 23rd October; 56 at Skinflats on 27th November, 5 at Cambuskenneth on 7th November and 22 on 12th December (NRF DM ARD CJH)

SWP in Drip Moss area from January to April 15th, max. 27 on 27th February; 21 at Thornhill on 21st January.
1st of autumn on October 30th at Thornhill and 31st at Carron Valley Reservoir and Drip Moss — max. here 71 on November 14th (21% imm) (JG CVG RLC GJ DT)

BEAN GOOSE
S 31 at Carron Valley Reservoir on 27th September, max. 52 on 17th October, last 47 on 31st October (CVG)

PINK-FOOTED GOOSE
C 100 at Alloa Inch on 17th April (WRB). Calling over Alva at 20.50 on 21st September (CJH)
S 2000 at Kippen on 24th February. 1 at Carron Valley Reservoir from 16th August. 4 at Gargunnock on 17th September and heard at Stirling on 19th, 80 SE over Dumyat on 21st October. 2500 at Gargunnock on 6th November. 560 at Grangemouth on 27th and 28th November and 650 S on 12th December (JG DM DT CVG)
SWP few around Blairdrummond in January, 2500 on 24th February and 3000 on 10th April — last on 15th. Leucistic bird at Lecropt on 14th November, 1500 at L. Watston on 6th (JG WRB DT)

GREYLAG GOOSE
C 140 on pasture at Cambus on 21st March (CJH)
S 1650 at Gargunnock on 20th February, last 20 on 12th April, 1400 on 6th November (JG DT)
2000 at Blairdrummond on 20th February, 4240 on 21st March between here and Flanders Moss (JG DT)
SWP 2000 Blairdrummond on 20th February, 1200 at L. Ruskie on 5th November (WRB DT)

*SNOW GOOSE
S 2 intermediate phase birds with Pinkfeet at Kippen late February to early March (JG)
SWP 2 (same birds) at Thornhill/Blairdrummond/Lecropt from 24th February to early March, 1 from 10th to 14th March (WRB JG GT DT)

CANADA GOOSE
C 3 at Gartmorn on 31st October and 28th November (WRB)
S 19 at Cambuskenneth on 10th January (WRB)

BARNACLE GOOSE
S 60 high to W at Skinflats on 26th September and 37 S on the 27th, 4 with Pinkfeet at Gargunnock on 6th November (DLC GMC JG)
SWP 1 at Blairdrummond on 13th February and 20-21st March. 3 at Thornhill on 27th February. 4 at L. Watston on 6th November and 11 at Lecropt on 14th (WRB JG DT)

*BRENT GOOSE
S 1 (light bellied) at Gargunnock with Pinkfeet and Greylags on 17th March (K. Barr)
4 (dark bellied) at Skinflats on 13th December (DMB)

SHELDUCK
C 2 by R. Devon at Alva on 22nd May (GJ)
S at Grangemouth — 1575 on 3rd January, 2100 on 17th February, 2765 on 13th November and 2235 on 13th December (DMB JS)
Moult flock at Kinneil, 2127 on 28th July (DMB)
SWP pair Blairdrummond on 8th May and 1 at Barbush on 22nd (GJ)

WIGEON

S 113 on Forth above Stirling on 21st February (JG)
301 at Carron Valley Reservoir on 31st October (CVG)

*GADWALL

C 7 at Gartmorn on 31st October (WRB)

S 1 at Bandeath on 13th January and 7 at Skinflats on 2nd October (WRB GMC)

SWP M at L. Watston on 9th June (WRB)

TEAL

C 66 by R. Devon at Tillicoultry on 30th January and 69 on 30th December. 280 at Tullibody Inch on 1st January. 60 at Cambus on 10th April (IMG CJH)

S 600 at Grangemouth on 13th December. 51 on Forth above Stirling on 10th December (DMB JG). 587 at Carron Valley Reservoir on 14th February and 1735 on 17th October, pair on 19th June (CVG)

MALLARD

C 600 at Tullibody Inch on 1st January. 1500 at Gartmorn Dam on 31st October and 1200 on 28th November (CJH WRB)

S 2229 at Carron Valley Reservoir on 31st October. 197 on Forth above Stirling on 10th December (DMB JG)

SWP 120 at L. Watston on 29th July and 130 at Blairdrummond on 11th September (WRB)

PINTAIL

C 1 at Tullibody Inch on 17th October (DMB)

S at Grangemouth, 30 on 24th January and 73 on 17th February, 149 on 13th November and 120 on 13th December (DMB WRB GMC JS)

*SHOVELER

C 7 at Gartmorn Dam on 31st October (WRB)

S at Grangemouth, 9 on 18th September and 2 on 24th October and 13th November (DMB). 1 at Bandeath on 13th January and 1 at Carron Valley Reservoir on 17th October (DHME WRB)

SWP M at L. Watston on 9th June (WRB)

POCHARD

S 307 at Carron Valley Reservoir on 31st October (CVG)

TUFTED DUCK

C 275 at Tullibody Inch on 1st January and 356 on the 13th — cold spell (WRB CJH)

S 42 at Cambuskenneth on 12th December (NRF)
157 at Carron Valley Reservoir on 29th August (CVG)
5 young at Touch Reservoir on 26th June (WRB)

*SCAUP

S at Grangemouth — 1 on 24th January, 1 on 18th September and 3 on 30th December. 1 at South Alloa on 17th October (DMB DT). 1 on 12th August and 2 on 13th November at Carron Valley Reservoir (CVG) (inland records unusual — Editor)

*LONGTAILED DUCK

C 1 immature at Gartmorn Dam on 11th and 27th November (IMG)

GOLDENEYE

C 55 at Cambus on 7th March (NRF)

S 93 at Carron Valley Reservoir on 6th November. 23 at Cambuskenneth on 26th November and 16th December (NRF DT)

SWP 37 at Lake of Mentieth on 25th March. Also at L. Ard, L. Chon, L. Watston and L.

Katrine January to March, max. 12 at L. Katrine on 13th March (WRB DMcE)

GOOSANDER

C 40 at Tullibody Inch on 1st January, still 7 at Cambus on 10th April (CJH). 17 on Glendevon Reservoir on 7th November (DMB)

S 24 at Cambuskenneth on 31st January, 8 on 19th May. 10 on Forth above Stirling on 21st February (JG GJ)

SWP F + 10Y at L. Lubnaig on 24th July, F + 8Y on R. Leny on 3rd July. 26 at L. Lubnaig on 31st July and 15 at L. Venachar on 27th August (WRB GJ)

RED-BREASTED MERGANSER

SWP 2M at L. Achray on 27th April (WRB)

HEN HARRIER

C 1 at Muckhart on 3rd October (DMB)

S at Sheriffmuir on 10th May, 15th and 16th September. 1 at Skinflats all January, also 23rd August to 3rd September and on 6th October. 1 at Carron Valley Reservoir on 19th September and North Third Reservoir on 11th November (DMB GMC CVG NRF DT)

SWP 1 at Kinbuck on 9th January and Cambusdrenny on 10th December (WRB JG). Persecution suspected.

BUZZARD

C 1 at Harvieston on 30th January (IMG)

S More in spring than usual : 1 Carron Valley Forest on 14th February. 2 at Buchlyvie on 6th February. 1 at Airthrey on 6th, 19th and 30th March. In Dumyat area 1 on 27th February and 5 on 5th March, also 2 on 15th and 1 on 22nd September, 2 on 23rd October (CVG NRF RC CJH)

SWP Frequent in Trossachs winter and spring. 7 at Dunblane on 13th November (DMcE DT)

GOLDEN EAGLE

S pair bred but failed (JM)

SWP In winter at Balquhidder, Strathyre, Ben Tulaichain, Glen Artney (WRB DMcE)

MERLIN

C 1 at Alva on 31st January (CJH)

S Male in Queen Elizabeth Forest on 18th June. 1 at Grangemouth on 3rd and 24th January, 13th and 30th December (DMB JM DT R. Shand). 1 at Skinflats on 14th and 20th January, 26th August and 28th November (WRB GMC)

PEREGRINE

S 2 pairs bred, one successfully (JM)
1 at Gargunnock 30th January and seen often in December
1 at Carron Valley Reservoir on 19th September. 1 at Grangemouth on 11th August and 17th February. 2 wintered at Skinflats January to April and from 26th August (JG DM CVG GMC RS)

BLACK GROUSE

S 6 roosted at Lossburn October and November (NF)

SWP 17 (13M) at Glen Artney on 5th December (DMcE)

*CAPERCAILLIE

SWP 1 at L. Ard on 9th April (RLC)

GREY PARTRIDGE

S 18 at Blairlogie on 10th January and 18 at Gargunnock in December (WRB JG)

SWP 25 Ashfield to Kinbuck on 9th January (WRB)

*QUAIL

SWP 1 at Drip Moss 7th to 13th June (WRB)

WATER RAIL

S 2 pairs at Parkfoot Marsh and at least 4 pairs at Carron Dam on 20th July (CVG)

CORNCRAKE

S 1 calling at Bannockburn on 21st and 22nd May (DT)

SWP 1 at Drip Moss on 27th May (D and I Jones)

COOT

SWP 139 at Lake of Menteith on 20th November (DT)

OYSTERCATCHER

C 1 at Muckhart on 31st January, night calls from 13th February (DMB)

S 1st at Gargunnock on 14th February (JG)

SWP 13 at L. Watston on 14th February. 1st at Ashfield on 12th February and 6 pairs there on 27th May. 100 at Doune Ponds on 21st February and 252 at Blackdub on 12th March (WRB JG DT)

RINGED PLOVER

S at Carron Valley Reservoir from 18th April, at least 7 pairs, last on 12th August (CVG)

SWP Bred at Blairdrummond.

GREY PLOVER

S 33 at Skinflats on 23rd January and 25 on 7th November (DLC GMC)

LAPWING

S Usual early autumn return to estuary : 2000 at Bandeath on 2nd August. 1400 at Pow Burn on 11th

340 at Kinneil on 10th and 400 on 23rd. 1200 at Skinflats on 11th September (WRB GMC DT)

SWP 650 at Lecropt on 14th November (DT)

KNOT

S 25 at Skinflats on 4th August. 1000 at Kinneil on 7th February, 2400 on 13th December (WRB DMB GMC DT)

*SANDERLING

S 2 at Skinflats on 4th August (GMC)

LITTLE STINT

S 1 at Kinneil on 29th August and 18th September (DMB R. Shand)

*CURLEW SANDPIPER

S 1 at Grangemouth on 29th August, 6 on 18th September and 2 on 2nd October (DMB GMC RS) (DMB R. Shand)

DUNLIN

S 3500 at Grangemouth on 7th February (WRB)

Probably bred at Carron Valley Reservoir, birds displaying in two places in June (CVG)

RUFF

C 4 at Cambus on 9th September and 2 at Craigrie Pond on 11th August (WRB)

S At Grangemouth from 10th August to 26th September, max. 9 on 23rd and 12 on 29th August (DMB DLC RS DT WRB)

JACK SNIPE

C 1 at Muckhart on 2nd December (DMB)

S 1 at Carron Valley Reservoir on 17th October (CVG)

SNIPE

S 4 along non-tidal Forth on 10th December (JG)

SWP 36 at Cromlix on 2nd August (WRB)

BLACK-TAILED GODWIT

S at Grangemouth mainly from 20th July to the max. 8 on 18th September. Also 1 on 27th April, 26 on 4th May to 2 on 24th May. 2 on 14th and 1 on 28th November, 1 on 12th and 2 on 30th December (DMB WRB GMC DT DLC RS)

CURLEW

S At Carron Valley Reservoir, Kippen Muir and Gargunnock from 14th February. 208 (at G.) on 11th March during cold weather. 5 pairs at Carron Valley Reservoir (JG CVG DT)
490 at Grangemouth on 18th September (DMB)

WHIMBREL

S at Grangemouth, 2 on 6th May, in August from 2nd to the max. 5 on the 26th (WRB GMC RS DT)

*SPOTTED REDSHANK

S 1 at Skinflats from January to March, 1 on 11th and 18th September and 30th December (DMB GMC DJ)

REDSHANK

C 200 NW over Cambus on 29th April (WRB)

S Spring return to Gargunnock on 21st March (JG)
734 at Grangemouth on 17th February and 790 on the 21st (GMC JS)

GREENSHANK

S at Grangemouth, 1 on 6th April. From 8th July to 17th October, max. 5 on 23rd August (GMC RS DT)

*GREEN SANDPIPER

C 1 at Cambus on 23rd August (WRB)

COMMON SANDPIPER

S Arrived at Carron Valley Reservoir on 18th April, at least 12 pairs bred, last seen on 19th September (CVG)

*TURNSTONE

S 21 at Skinflats on 17th February (CVG). 1 at Kinneil on 10th August (DT)

ARCTIC SKUA

S 18 at Skinflats on 5th September flew in low from the WSW, i.e. from inland (DMB). Also 1 at Kinneil on 20th July (DT)

GREAT SKUA

S 1 (sickly) on mud at Skinflats on 7th November (DLC)

BLACK-HEADED GULL

S 88 pairs at Carron Valley Reservoir, fewer than usual and all failed due to low water (CVG)

SWP 300 pairs at Blairdrummond and 30 at Ashfield (WRB)

COMMON GULL

S 1100 on ploughland at Arnprior on 11th February (JG)

LESSER BLACK-BACKED GULL

S/SWP 1st inland on 5th March (DT)

HERRING GULL

S 1500 at Kinneil rubbish tip on 18th December (WRB)

GLAUCOUS GULL

S 1 at Stirling on 7th March (RLC)

KITTIWAKE
C 1 W at Cambus on 14th April (WRB)
S 400 at Skinflats on 21st May and 400 on 5th September (DMB GMC)

SANDWICH TERN
S 220 at Skinflats on 14th September (GMC)

COMMON TERN
S At Grangemouth up to 100 adults in summer, ca 55 nests (as 1979). 25+ young seen on 16th June (DM)

*BLACK TERN
S 6 at Grangemouth on 18th September, 2 on 20th (DMB GMC)

*GUILLEMOT
S 2 at Skinflats on 11th February (GJ)

COLLARED DOVE
C 20 at Cambus distillery on 5th December (CJH)

CUCKOO
S 1st at Gargunnock on 9th May, numbers high (JG)

*BARN OWL
S 1 at Kippen on 25th March
SWP 1 at Keir on 19th February and 20th April (WRB)

TAWNY OWL
S Still scarce at Gargunnock (JG)

SHORT-EARED OWL
S 2 pairs in Carron Valley Forest, 5 records August-December (CVG). None Sheriffmuir. 3 at Bannockburn on 10th January. 1 at Loch Coulter on 1st April and 29th August, North Third Reservoir on 14th November. 1 at Skinflats on 14th January and 14th March (GMC WRB RLC NRF)

SWIFT
S 1st records — 20 at Stirling on 6th May, 3 at Gargunnock on 8th, 2 at Bridge of Allan on 5th and 9 there on 11th
1 at Stirling on 10th and Airthrey on 16th September (NRF JG DT)

*KINGFISHER
S 1 at Skinflats on 9th September (GMC). Reported from Bridge of Allan in autumn.

SKYLARK
C singing at 300m in Ochils on 26th February (IMG)
S 13 E at Blairlogie on 24th September. 75 at Kinneil on 12th December and 100 on 18th (WRB JG DT)

SANDMARTIN
S 6 at Airthrey on 29th March and 15 on 30th. 5 pairs Avon Glen sandpit (only known Falkirk District colony). 33 birds at Denny pit NS827820 on 21st July. 420 roosting at Carron Dam on 20th July (WRB NF AW AY)
SWP 2 at Barbush on 2nd April. 200 at Lake of Menteith on 5th (WRB DT)

SWALLOW
S 1st, 2 at Airthrey on 18th April. Last, 10 at Plean and 5 at Buchlyvie on 6th October (RLC NRF DT)
SWP 2 at Lake of Menteith on 8th April. Last, 6 at Doune to 6th November (WRB DT)

HOUSE MARTIN
C at Cambus on 5th September 1 fed in a larch and was mobbed by Chaffinches, Blue and Great Tits (WRB)

S 1st at Airthrey on 4th May and at Gargunnock on 6th
Last at Bridge of Allan on 29th September (JG NF)
In Carron Valley, 47 pairs at E. Craigannet and 3 at Muirmill (CVG)
SWP 20 pairs at Ashfield (normal). 3 Stronachlachar (WRB CVG)

TREE PIPIT
S 1st at Cocksburn on 20th April (NRF)
SWP 1st at Brig o' Turk and Lake of Menteith on 18th April
Last over Stirling on 3rd September (WRB DMcE)

MEADOW PIPIT
C 45 in ley grass at Alva on 26th March (CJH)
S 74 at Pendreich on 31st March. 70 at Sheriffmuir and 90 at Carron Valley Reservoir on 19th September (CVG NF)
SWP Frequent and singing in Torrie Forest on 20th March (CJH)

*ROCK PIPIT
S 1 at Carron Valley Reservoir on 17th October (CVG) (first ever record from inland — Editor)

YELLOW WAGTAIL
S at Kinneil on 8th July the male of a pair with 2 juveniles resembled the race iberiae with short white eyestripe behind eye, cheeks darker grey than crown and chin yellowish. Family present on 20th July and one on 23rd August (DT)

GREY WAGTAIL
midwinter records:
C 2 at Tillicoultry on 30th December (IMG)
S 1 at Fallin on 22nd January (WRB)

PIED WAGTAIL
C 45 roosting in reedmace at Alva pools on 2nd August (CJH)

*WHITE WAGTAIL
C 2 at Cambus on 17th and 14 on 26th April (WRB)
S 3 at Carron Valley Reservoir on 18th April (CVG)

*WAXWING
S 1 at Alloa on 24th February (RLC)

DIPPER
C out of breeding range: 1 on burn east of Alloa on 23rd January (WRB)
S pairs at Carron Valley Reservoir and Earlsburn (CVG)
SWP pairs at Kinlochard and west L. Katrine (DMcE)

WREN
SWP estimated 50% decline after hard winter (WRB)

*BLACK REDSTART
S 1 F/imm at Kinneil on 12th and 18th December (WRB DT)

REDSTART
S Only records in early autumn, presumably dispersal, at Gargunnock and Carron Valley Forest (JG CVG)
SWP 1st at Kilmahog on 24th April. In breeding season at Stronachlachar and Rednock (WRB DMcE CVG)

WHINCHAT
S 1st at Stirling on 27th April, decreased at Gargunnock. Autumn movement: 10 at Carron Valley Forest on 12th August (NF JG CVG)

*STONECHAT
No breeding season records
S 1 at Skinflats on 17th February (JS)

WHEATEAR

S 1st at Airthrey on 26th March (NF)
Last at North Third Reservoir on 7th November (CVG)

SWP 2 at Barbush GP on 6th April (WRB)

FIELDFARE

C 1100 W along Ochil scarp on 24th October. 7500 at Cambus on 30th October (WRB NRF IMG)

S 1st at Gargunnock on 9th October. In winter 320 at Kippen Muir on 26th December (JG)

SWP 310 at Blairdrummond on 14th April. In winter 240 at Lecropt on 4th December (WRB JG)

SONG THRUSH

SWP Spring return to Ashfield on 11th February, Kinlochard and Glengyle on the 21st (WRB DMcE)

REDWING

C 500 at Cambus on 30th October (WRB)

S 1st at Airthrey on 7th October, Gargunnock on 9th and Stirling on 11th (WRB NF JG)

MISTLE THRUSH

S 20 in Carron Valley Forest on 12th August (CVG)

SWP Singing at Kinlochard and Glengyle on 21st February (DMcE)

SEDGE WARBLER

S 1st at Lower Polmaise on 26th April. 1st at Gargunnock on 9th May, good numbers (WRB JG)

SWP Singing at Inverlochlarig (Balquhidder) on 6th June — far up the glen (WRB)

BLACKCAP

S Female at Airthrey on 25th November and 5th December. Male at Bridge of Allan on 26th November (NF IMG)

WOOD WARBLER

SWP 1st in Trossachs on 28th April, 12 singing in 4 km on 23rd May (WRB DMcE)

CHIFFCHAFF

S 1st at Airthrey on 25th March (IMG)

SWP Singing at L. Ard, Aberfoyle, L. Achray. Lake of Menteith, scarcer than usual (WRB RLC DMcE)

WILLOW WARBLER

S 1st at Gargunnock on 16th April, Carron Dam on 17th, Airthrey on 18th (NF JG)
76 (flock) at Carron Valley Forest on 23rd July (CVG)

SWP 3 at Port of Menteith on 8th April (WRB)

GOLDCREST

SWP Apparently little affected by January freeze (WRB DT)

LONG-TAILED TIT

S 26 at Gargunnock on 17th January. 15 at Pendreich on 11th November and 40 at Abbey Craig on the 26th (WRB JG IMG)

SWP 20 at Doune on 6th November (WRB)

COAL TIT

SWP 40 at Menteith on 18th April and 30 at Aberfoyle on 9th August (WRB DMcE)

GREAT GREY SHRIKE

S 1 at Carron Valley Forest on 31st October and 1 at Bannockburn on 28th November (RLC CVG)

JAY

S autumn and winter records from Sheriffmuir, Airthrey, Kippen and Gargunnock

SWP in breeding season at Strathyre, Brig o' Turk, Menteith, Aberfoyle, L. Chon

MAGPIE

SWP 1 near Gartmore on 13th March — further extension to west (DMcE)

JACKDAW

C 120 at Tillicoultry on 29th March (IMG)

ROOK

C nests in rookeries: 270 at Menstrie, 35 in hillside copse above Myreton NS858975 (previously unrecorded, probably recent colony) (CJH)

RAVEN

S Low ground records — 1 over Gargunnock on 14th February, 2 at Bridge of Allan on 27th September, 1 at Carron Valley Forest on 14th February (JG NRF CVG)

SWP Recorded from Kinlochard, L. Katrine, Aberfoyle, Menteith, max. 5 over west L. Katrine on 17th July (WRB CVG)

HOUSE SPARROW

S 10 at Skinflats on 21st August (WRB)

TREE SPARROW

C 25 at Blackdevonmouth on 28th February (CJH)

S Bred at Denny (CVG). 25 at Bannockburn on 22nd January. 60 at Touch and 18 at Gargunnock on 21st February. 24 at Skinflats on 11th September and 16 at Kippen on 28th November (GMC JG DT)

CHAFFINCH

S singing strongly at Airthrey on 17th February, mild spell. 685 at Carron Valley Reservoir on 19th September, 1150 on 12th December (CVG CJH)

SWP 450 at Cromlix on 19th December (WRB)

BRAMBLING

S 1st at Carron Valley on 15th October, 20 on 20th November. 20 at Slamannan on 14th February (WRB CVG)

SWP 6 at Blairdrummond on 2nd January (JG)

GREENFINCH

S 250 at Skinflats on 21st August. 90 at Kippen on 28th November (WRB JG)

GOLDFINCH

C 14 at Cambus on 27th March (WRB)

S 25 at Pendreich on 1st and 14 at L. Coulter on 14th November. 80 (roost) at Airthrey on 16th December (NRF WRB IMG)

SISKIN

C 45 at Tillicoultry on 20th November (IMG)

S 2 at Carron Valley Forest on 19th June (CVG). 62 at Bannockburn on 28th November (RLC)

SWP In breeding season at Strathyre, Menteith, L. Achray, E and W L. Katrine (WRB DMcE). 60 at Lake of Menteith on 20th November (DT)

LINNET

S 150 at Gargunnock on 17th January and 60 at Skinflats on the 9th. 130 at Kinneil on 18th December (WRB GMC JG)

SWP 300 at Cambusdrenny on 10th December (JG)

TWITE

S 16 in Stirling town on 15th October (RLC). 10 at Airth shore on 17th January and 15 on 12th December. 80 at Skinflats on 28th November and Kinneil on 18th December (WRB CJH)

REDPOLL

C 30 at Harviestoun on 20th November (IMG)

S 36 at Meiklewood on 13th November, 32 at Airthrey on 30th November and 60 on 7th December (JG IMG)

CROSSBILL

S at Carron Valley Forest, 1 on 23rd July, 45 on 13th November and 18 on 12th December. 11 at Cocksburn Reservoir on 29th October (NRF CVG)

SWP 6 (family) at L. Achray on 18th April. 25 in Menteith Hills on 20th November (WRB)

*HAWFINCH

S 1 at Bridge of Allan on 6th July (WRB)

SWP Pair at Doune on 16th March, 1 on 12th November (WRB)

SNOW BUNTING

S 1 at Skinflats on 13th November and 9 at Cocksburn on 10th January (WRB DMB)

SWP 60 at Glengyle on 13th March (DMcE)

YELLOWHAMMER

C 50 at Alloa on 23rd January. Still in groups of 6 at Alva on 11th April (WRB CJH)

S 70 at Gargunnock on 21st February and 70 at Kippen on 28th November (JG)

REED BUNTING

S 50 at Bannockburn on 9th January (DT)

*CORN BUNTING

C 6 at Cambus on 27th March (WRB). Apparently extinct on carse around Menstrie (CJH)

S 1 at Bellsdyke on 9th May. At Skinflats 1 on 27th April and 9 on 21st August. None west of Stirling (WRB)

Additional records for 1980 —

*BLUETHROAT

S A male of the Red-spotted form in a garden at Grangemouth on 16th May 1980. Record submitted with colour photographs by W. B. Templeton

LEPIDOPTERA OF THE FALKIRK DISTRICT OF CENTRAL REGION

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Lists of Lepidoptera occurring in the Stirling area have been compiled by M. and A. McLaurin (1928–29) and D. L. Coates (1968). Both were centered on Stirling, covering areas of twelve and twenty miles radius respectively, and should therefore have included the south-eastern part of Stirlingshire, now the Falkirk District of Central Region. However, there seems to have been something of a bias towards the North and West, for almost all of the actual localities cited by these authors were situated there. This is perhaps not surprising since in that direction the habitats are much more varied and rewarding for the entomologist. Thomson (1968) in his notes and additions to Coates' list dealt almost exclusively with the same area. The present list, on the other hand, is heavily biased towards the vicinity of Falkirk, the vast majority of records being derived from a light trap (mercury vapour/uv) at North Bantaskine (Grid Reference NS 878802). It should therefore supplement the above lists and help to give a more balanced picture of Vice-county 86 (Stirlingshire) when considered along with them. Over fifty years have elapsed since the McLaurin brothers were collecting, and in view of rather large scale industrial developments and reaforestation which have taken place in the interim and which affect some of the more interesting habitats in Falkirk District, the present list may also provide a basis for monitoring the significant environmental changes which are taking place.

The largest habitats in Falkirk District remaining relatively free from human activity at present consist of coarse pasture, raised bog (much of this, however, being extensively worked for peat) and old mining areas which have become covered with heath and birch scrub. There are one or two fairly large areas of deciduous woodland, but here again there has been much replacement by coniferous plantations and a certain amount of disturbance by the general public. Some of the woodland and heath areas are coming under increasing pressure from encroaching building, by dumping of rubbish and by acts of vandalism, as at Blaeberry Mair just west of Falkirk. While the insects resident in this and other affected areas can hardly be described as endangered species, some have been noted from only a single locality in the District and their loss would be unfortunate indeed. Under such circumstances it is not surprising that recent records of the Lepidoptera of Falkirk District contained comparatively few references to species requiring specialised or undisturbed habitats.

It has been widely noticed in recent years that there has been an extension of the ranges of a number of species in Scotland involving both long term residents, for example the Orange Tip (*Anthocharis cardamines* (Linnaeus)) Long 1979, 1980 and Thomson 1978 and the Purple Hairstreak (*Quercusia quercus* (Linnaeus)) Thomson pers comm, and presumed recent arrivals such as *Caloptilia rufipennella* (Hubner) Shaw 1981. Further examples of both types of range extension (details of circumstances are given in the list) are believed to have been encountered in the cases of *Orgylia antiqua* (Linnaeus) and *Deilephila elpenor* (Linnaeus) as long term residents and of *Lomographa temerate* and *Xanthia gilvago* (Denis and Schiffermuller) and *Melanchra persicariae* (Linnaeus) as recent arrivals. Whether this phenomenon is likely to persist is not certain, for in 1981 no specimens of *D. elpenor or X. gilvago* were noted in Falkirk District. However, there has been a partial recovery in 1982, and it seems from the increased numbers of many species, that the very severe winter of 1981–82 has had a beneficial effect rather than the reverse. Apparent local extinctions of what seem to be reasonably tolerant species, whether or not they follow an extension of range, are part of the same general phenomenon. Thus dramatic and more permanent population collapses than in the cases of *D. elpenor* and *X. gilvago* in 1981, have been seen in *Operophtera fagata* (Scharfenberg) in 1971 and *Gortyna flavago* (Denis and Schiffermuller) in 1973 in my own immediate neighbourhood.

In an area which is not intensively studied the status of any species which is not fairly common and widespread must necessarily be in some doubt. The majority of the species in this list have been taken in my light trap situated about three quarters of a mile from the centre of Falkirk, and obviously only the occasional straggler from any specialised habitat such as a raised bog, the nearest of which is about three miles distant, would be recorded. Nor are all species, even when present, readily taken in such traps. Consequently it is possible that some of the species categorised as 'rare' may in fact be locally quite common or even more generally so. Nevertheless it is desirable to give some idea of status, and this has been attempted as follows —

1. Absence of comment indicates that the species may be found more or less every year in numbers upwards of five. (Records of 'Microlepidoptera' are, however, except in a few special cases, all unannotated for want of information.)
2. 'Not common' indicates similar regular occurrence in numbers of less than five.

3. 'Sporadic' means the insect has occurred from time to time with one or two-year intervals and in variable numbers.
4. 'Uncommon' indicates a similar time pattern but in very small numbers (one or two).
5. 'Rare' means less than five specimens noted in the twenty or so years covered. All dates are given; a few records from as far back as the 1940's are included.
6. Localities are given only where these are other than my own garden, but it does not follow that where no locality is mentioned, the insect has not been found elsewhere. Additional comments are made where thought desirable.

The list follows the order and nomenclature of Kloet and Hincks (1972), but no account has been taken of subspecies. All records given are of my own captures. 'Macrolepidoptera' and Hepialidae were comprehensively sampled, but records of day-flying species (Pieridae to Saturniidae and a few isolated species in other families) are not complete as they could not be sought on the same regular basis. The families of 'Microlepidoptera' (Eriencraniidae to Pterephoridae, apart from Hepialidae) were sampled only casually and I can make no claim to provide a representative list of what actually occurs in these families.

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LEPIDOPTERA

ERIOCRANIIDAE

Dyseriocrania subpurpurella (Haworth)

Eriocrania sangii (Wood)

HEPIALIDAE

Hepialus humuli (Linnaeus)

H.hecta (Linnaeus)

Records incomplete as has to be actively sought in the field. Common where found — not at N.Bantaskine.

H.lupulins (Linnaeus)

Rare 16 June 1949 S Bantaskine

H.fusconebulosa (De Geer)

NEPTICULIDAE

Trifurcula immundella (Zeller)

INCURVARIIDAE

INCURVARIINAE

Nematopogon swammerdamella (Linnaeus)

ADELINAE

Adela reamurella (Linnaeus)

TINEIDAE

DRYADAULINAE

Dryadaula pactolia Meyrick

This species is a native of New Zealand, but has been established in the south of England for some time. It has been found more recently in a distillery in Edinburgh where the larva was found feeding on the mould underneath the casks (Morrison 1968). The specimen in my collection was taken in the trap at Falkirk. This was, perhaps significantly, situated only about 300 m from a distillery. This is only the second record from Scotland.

NEMAPOGONINAE
Nemapogon cloacella (Haworth)

TINEINA
Monopis weaverella (Scott)
Tinea semifulvella Haworth
T.trinotella Thunberg

LYONETIIDAE

CEMIOSTOMINAE
Leucoptera laburnella (Stainton)
L.spartifoliella (Hubner)

LYONETIINAE
Lyonetia clerkella (Linnaeus)

GRACILLARIIDAE

GRACILLARIINAE
Caloptilia azaleella (Brants)

A southern species often semi-established as a local escape from azaleas grown under glass. This is believed to be the first record from Scotland.

C.alchemiella (Scopoli)
C.syringella (Fabricius)

LITHOCOLLETINAE
Phyllonorycter quercifoliella (Zeller)
P.messaniella (Zeller)

GLYPHIPTERIGIDAE

CHOREUTINAE
Anthophila fabriciana (Linnaeus)

YPONOMEUTIDAE

ARGYRESTHIINAE
Argyresthia semifusca (Haworth)
A.pruniella (Clerck)
A.curvella (Linnaeus)

YPONOMEUTINAE
Yponomeuta evonymella (Linnaeus)
Cedestis gysseleniella Zeller
C.subfasciella (Stephens)
Prays fraxinella (Bjerkander)

PLUTELLINAE
Ypsolopha dentella (Fabricius)
Y.parenthesella (Linnaeus)
Y.ustella (Clerck)
Y.vittella (Linnaeus)
Plutella xylostella (Linnaeus)

P.porectella (Linnaeus)

EPERMENIIDAE

Epermenia chaerophyllella (Goeze)

ELACHISTADAE

Elachista rufocinerea (Haworth)
E.alpinella Stainton
E.atricomella Stainton

OECOPHORIDAE

OECOPHORINAE

Borkhausenia fuscescens (Haworth)
Endrosis aarcitrella (Linnaeus)
Carcina quercana (Fabricius)
Diurnia fagella (Denis and Schiffermuller)
Hofmannophila pseudospretella (Stainton)

DEPRESSARIINAE

Depressaria pastinacella (Duponchel)
Agonepterix heracliana (Linnaeus)
A.ocellana (Fabricius)
A.nervosa (Haworth)
A.liturosa (Haworth)

GELECHIIDAE

GELECHIINAE

Teleoides decorella (Haworth)
Bryotropha terella (Denis and Schiffermuller)
Lita virgella (Thunberg)

BLASTOBASIDAE

Blastobasis lignea Walsingham
B.decolorella (Wollaston)

MOMPHIDAE

BATRACHEDRINAE

Batrachedra praengusta (Haworth)

MOMPHINAE

Mompha raschkiella (Zeller)
M.propinquella (Stainton)

BLASTODACNINAE

Blastodacna hellerella (Duponchel)

TORTRICIDAE

OLETHREUTINAE

Cydia succedana (Denis and Schiffermuller)
C.aurana (Fabricius)
Enarmonia formosana (Scopoli)

Eucosma hobenwartiana (Denis and Schiffermuller)
E. cana (Haworth)
Epiblema cynosbatella (Linnaeus)
Zeiraphera diniana (Guenee)
Rhopobota unipunctana (Haworth)
Epinotia stroemiana (Fabricius)
E.caprana (Fabricius)
E.ramella (Linnaeus)
E.immundana (Fischer von Roslerstamm)
E.nisella (Clerck)
E.cruciana (Linnaeus)
E.mercuriana (Frolich)
Ancylis badiana (Denis and Schiffermullar)
Lobesia littoralis (Humphreys and Westwood)
Hedya nubiferana (Haworth)
Orthotaenia undulana (Denis and Schiffermuller)
Olethreutes lacunana (Denis and Schiffermuller)

TORTRICINAE
Pandemis cerasena (Hubner)
P.heparana (Denis and Schiffermuller)
Archips xylosteana (Linnaeus)
A.rosana (Linnaeus)
Syndemis musculana (Hubner)
Clepsis spectrana (Treitschke)
Lozotaenia forsterana (Fabricius)
Capua vulgana (Frolich)
Ditula angustiorana (Haworth)
Pseudargyrotoza conwagana (Fabricius)
Eulia ministrana (Linnaeus)
Cnephasia stephensiana (Doubleday)
C.interjectana (Haworth)
C.incertana (Treitschke)
Expate congelatella (Clerck)
Tortrix viridana (Linnaeus)
C.forsskaleana (Linnaeus)
Acleris latifasciana (Haworth)
A.commariana (Lienig and Zeller)
A.sparsana (Denis and Schiffermuller)
A.rhombana (Denis and Schiffermuller)
A.aspersana (Hubner)
A.ferrugana (Denis and Schiffermuller)
A.variegana (Denis and Schiffermuller)
A.hastiana (Linnaeus)
A.hyemana (Haworth)
A.emargana (Fabricius)

COCHYLIDAE
Agapeta hamana (Linnaeus)
Aethes piercei (Obraztsov)
A.rubigana (Treitschke)
Eupoecilia angustana (Hubner)

ALUCITIDAE
Alucita haxadactyla (Linnaeus)

PYRALIDAE

CRAMBINAE
Chrysoteuchia culmella (Linnaeus)
Crambus nemorella (Hubner)
Agriphila straminella (Denis and Schiffermuller)
A.tristella (Denis and Schiffermuller)
Catoptria pinella (Linnaeus)
C.margaritella (Denis and Schiffermuller)

SCOPARIINAE
Scoparia arundinata (Thunberg)
S.ambigualia (Treitschke)
Eudonia murana (Curtis)
E.angustea (Curtis)
E.mercurella (Linnaeus)

NYMPHULINAE
Nymphula nymphaeata (Linnaeus)

EVERGESTIINAE
Evergestis forficalis (Linnaeus)

PYRAUSTINAE
Margaritia sticticalis (Linnaeus)
Eurrhypara hortulata (Linnaeus)
Udea lutealis (Hubner)
U.prunalis (Denis and Schiffermuller)
U.ferugalis (Hubner)
Nomophila noctuella (Denis and Schiffermuller)
Pleuroptya ruralis (Scopoli)

PHYCITINAE
Pyla fusca (Haworth)

PTEROPHORIDAE

PLATYPTILIINAE
Platyptilia gonodactyla (Denis and Schiffermuller)
P.pallidavtyla (Haworth)
Stenoptilia pterodactyla (Linnaeus)

PIERIDAE

PIERINAE

Pieris brassicae (Linnaeus)
P.rapae (Linnaeus)
P.napi (Linnaeus)

LYCAENIDAE

THECLINAE

Callophrys rubi (Linnaeus)
Large colony on heathland to the west of Falkirk

LYCAENINAE

Lycaena phlaeas (Linnaeus)
Polyommatus icarus (Rottenburg)

NYMPHALIDAE

Vanessa atalanta (Linnaeus)
A few most years
Cynthia cardui (Linnaeus)
Occasionally common, e.g. in 1980
Aglais urticae (Linnaeus)
Inachia io (Linnaeus)
Rare 4 August 1977 (1), 27 August 1977 (3)
Boloria selene (Denis and Schiffermuller)
Common in one of two small colonies at Blaeberry Mair and Roughcastle, but under threat from industrial development.

SATYRIDAE

Maniola jurtina (Linnaeus)
Coenonympha pamphilus (Linnaeus)
C.tullia (Muller)
Was common at Letham Moss, but is now under threat from peat extraction.

LASIOCAMPIDAE

Macrothylacia rubi (Linnaeus)
Rare 8 June 1973

BATURNIIDAE

Saturnia pavonia (Linnaeus)
Common on heaths

DREPANIDAE

Drepana falcataria (Linnaeus)

THYATIRIDAE

Thyatira batis (Linnaeus)
Ochropacha duplaris (Linnaeus)
Uncommon
Achlya flavicornis (Linnaeus)

GEOMETRIDAE

OENOCHROMINAE

Alsophila aescularia (Denis and Schiffermuller)
One at N Bantaskine on 10 March 1981. A number at Roughcastle February/March 1982.

GEOMETRINAE

Geometra papilionaria (Linnaeus)
Uncommon

STERRHINAE

Scopula ternata (Schrank)
Common at Blaeberry Mair. Could be affected by industrial development.

Idaea biselata (Hufnagel)
Rare 27 July 1982

I.seriata (Schrank)
Rare 17 June 1958

I.aversata (Linnaeus)

LARENTIINAE

Xanthorhoe designata (Hufnagel)

X.munitata (Hubner)
Rare 27 July 1963, 31 July 1967, 5 August 1967, 10 August 1968, 12 August 1968

X.montanata (Denis and Schiffermuller)

X.fluctuata (Linnaeus)

Scotopteryx chenopodiata (Linnaeus)

Epirrhoe tristata (Linnaeus)

E.Alternats (Muller)

Camptogramma bilineata (Linnaeus)

Entephria caesiata (Denis and Schiffermuller)
Carron Valley, uncommon (Stirling District)

Anticlea badiata (Denis and Schiffermuller)
Uncommon

A.derivata (Denis and Schiffermuller)
Rare 25 May 1970, 14 May 1982

Mesoleuca albicillata (Linnaeus)
Rare 20 June 1978, 11 July 1981, 14 July 1982

Pelurga comitata (Linnaeus)
Rare 27 July 1982

Lampropteryx suffumata (Denis and Schiffermuller)

Cosmorhoe ocellata (Linnaeus)

Eulithis prunata (Linnaeus)
Rare 21 July 1980, 28 July 1980

E.testata (Linnaeus)

E.populata (Linnaeus)

E.mellinata (Fabricius)
Sporadic

E.pyraliata (Denis and Schiffermuller)
Ecliptopera silaceata (Denis and Schiffermuller)
Chloroclysta siterata (Hufnagel)
Rare 10 Oct 1976, 5 Oct 1979, 25 Sept 1980
C.citrata (Linnaeus)
C.truncata (Hufnagel)
Cidaria fulvata (Forster)
Thera firmata (Hubner)
Common in coniferous plantations
T.obeliscata (Hubner)
T.juniperata (Linnaeus)
Rare 24 Oct 1968, 18 Oct 1969
Electrophaes corylata (Thunberg)
Colostygia multistrigaria (Haworth)
C.pectinataria (Knoch)
Common near coniferous plantations
Hydriomena furcata (Thunberg)
H.impluviata (Denis and Schiffermuller)
Rare Carron Valley 10 June 1969
Epirrita dilutata (Denis and Schiffermuller)
E.autumnata (Borkhausen)
Uncommon
E.filigrammaria (Herrich-Schaffer)
Uncommon
Operophtera brumata (Linnaeus)
O.fagata (Scharfenburg)
Not seen since 1970. 7 in 1965, 2 in 1967, 8 in 1969, 8 in 1970. Actual records not kept prior to 1965, but appeared to be quite common.
Perizoma alchemillata (Linnaeus)
(P. blandiata) (Denis and Schiffermuller)
Rare 3 July 1970, 11 Aug 1973, 12 Aug 1973, 25 July 1980, 1 Aug 1982
P.albulata (Denis and Schiffermuller)
Rare 9 July 1975
P.flavofasciata (Thunberg)
Not common
P.didymata (Linnaeus)
Eupithecia tenuiata (Hubner)
Common since 1978.
E.linariata (Denis and Schiffermuller)
Uncommon
E.pulchellata Stephens
Uncommon

E.valerianata (Hubner)
Rare 12 June 1979, 19 June 1979
E.centauriata (Denis and Schiffermuller)
Rare 23 June 1973, 3 July 1973, 13 July 1974, 2 Aug 1979, 15 June 1982
E.satyrata (Hubner)
Uncommon
E.absinthiata (Clerck)
Not common
E.goossensiata Mabılle
Rare 7 July 1973, 16 June 1975, 9 July 1978
E.assimilata Doubleday
Uncommon
E.vulgata (Haworth)
E.tripunctaria Herrich-Schaffer
E.subfuscata (Haworth)
E.icterata (Villers)
E.succenturiata (Linnaeus)
Not common
E.simpliciata (Haworth)
Rare 23 July 1982. This is the first record of this species in Scotland north of the Solway since 1871 (White 1871)
E.indigata (Hubner)
Rare 23 May 1981
E.nanata (Hubner)
Sporadic
E.fraxinata Crewe
Uncommon
E.abbreviata Stephens
not common
E.pusillata (Denis and Schiffermuller)
E.lariciata (Freyer)
Rare
E.tantillaria Boisduval
Not common
Chloroclystis v-ata (Haworth)
Rare 2 on 17 May 1978
C.rectangulata (Linnaeus)
Chesias legatella (Denis and Schiffermuller)
Carsia sororiata (Hubner)
Rare 22 August 1969
Aplocera plagiata (Linnaeus)
Rare 13 September 1971, 5 July 1981, 25 July 1982, 28 July 1982
Odezia atrata (Linnaeus)

Acasis viretata (Hubner)
Rare 25 May 1977

ENNOMINAE

Abraxas grossulariata (Linnaeus)
Uncommon

Semiothisa liturata (Clerck)
Not common

S.clathrata (Linnaeus)

S.wauaria (Linnaeus)

Pterophora chlorosata (Scopoli)

Opisthograptis luteolata (Linnaeus)

Pseudopanthera macularia (Linnaeus)
Common around Braes Wood and Auchenbowie (Stirling District)

Selenia dentaria (Fabricius)

S.lunaria (Hubner)
Rare 7 June 1967, 11 June 1979, 18 June 1979, 18 May 1981, 6 June 1981

Odontopera bidentata (Clerck)

Crocalis elinguaria (Linnaeus)

Ourapteryx sambucaria (Linnaeus)
First seen in 1971. Numbers increasing gradually to 21 in 1982

Colotois pennaria (Linnaeus)
Rare 8 Oct 1979, 12 Oct 1979, 28 Sept 1980

Apocheima pilosaria (Denis and Schiffermuller)
Not common

Biston betularia (Linnaeus)

Agriopis aurantiaria (Hubner)
Absent until 1975. Now common.

A.marginaria (Fabricius)

Erannis defoliaria (Clerck)
Sporadic

Peribatodes rhomboidaria (Denis and Schiffermuller)

Alcis repandata (Linnaeus)

Ectropis bistortata (Goeze)
Rare Muiravonside 10 May 1980

Ematurga atomaria (Linnaeus)
Common on heaths

Bupalus piniaria (Linnaeus)

Cabera pusaria (Linnaeus)

C.exanthimata (Scopoli)

Lomographa temerata (Denis and Schiffermuller)
Only one known previous record from Central Scotland (McLaurin 1973). First specimen in Stirlingshire noted at Falkirk on 8 June 1970. Found since at Auchenbowie (Stirling District) and also at

Falkirk on 26 May 1981, 5 June 1981, 5 June 1982 (2), 6 June 1982

Campaes margaritata (Linnaeus)

Hylaea fasciaria (Linnaeus)

Not common

Gnophos obfuscata (Denis and Schiffermuller)

Rare 5 Oct 1973, 20 August 1976

Dyscia fagaria (Thunberg)

Rare 19 June 1978

Perconia strigillaria (Hubner)

Common at Letham Moss, but under threat from peat extraction.

SPHINGIDAE

SPHINGINAE

Agrius convolvuli (Linnaeus)

Rare 5 September 1964

Laothoe populi (Linnaeus)

MACROGLOSSINAE

Deilephila elpenor (Linnaeus)

This species has been recorded around Stirling from time to time. A sudden upsurge in numbers began in 1977 and reached a maximum of 22 in 1979. It was still common in 1980, but in 1981, a poor year generally, none were seen. Two were noted in 1982 and it remains to be seen whether or not the high level of the late 1970's returns.

D.porcellus (Linnaeus)

Rare 12 July 1958, 18 June 1979

NOTODONTIDAE

Phalera bucephala (Linnaeus)

Uncommon

Cerura vinula (Linnaeus)

Rare Glen Village 27 May 1945

Harpyia furcula (Clerck)

Uncommon

Notodonta dromedarius (Linnaeus)

Eligmodonta ziczac (Linnaeus)

Pheosia gnoma (Fabricius)

Uncommon

P.tremula (Clerck)

Uncommon

Ptilodon capucina (Linnaeus)

LYMANTRIIDAE

Orgyia antiqua (Linnaeus)

A fairly widespread species in Scotland, but not mentioned by Coates (1968) nor seen by myself until 1981 when it suddenly appeared in quite large numbers in surburban areas of Falkirk and Larbert and in scrub birch and heathland areas to the south-west of Falkirk.

ARCTIIDAE

ARCTIINAE

Parasemia plantaginis (Linnaeus)
Uncommon in heathland at Blaeberry Mair and Roughcastle common around Grangemouth. Uncommon at Falkirk.

Arctia caja (Linnaeus)

Spilosoma lubricipeda (Linnaeus)

Phragmatobia fuliginosa (Linnaeus)
Rare Carron Valley 15 June 1967 (Stirling District)

NOCTUIDAE

NOCTUINAE

Euxoa nigricans (Linnaeus)

Agrotis segetum (Denis and Schiffermuller)

A.exclamationis (Linnaeus)

A.ipsilon (Hufnagel)

Axylia putris (Linnaeus)
Not common

Ochropleura plecta (Linnaeus)

Standfussiana lucernea (Linnaeus)
Rare 3 August 1974

Noctua pronuba (Linnaeus)

N.comes (Hubner)

N.frimbriata (Schreber)
Sporadic

N.janthina (Denis and Schiffermuller)

Graphiphora sugur (Fabricius)

Paradiarsia glareosa (Esper)

Lycophotia porphyrea (Denis and Schiffermuller)

Peridroma saucia (Hubner)
Uncommon

Diarsia mendica (Fabricius)
Not common

D.dahlii (Hubner)
Uncommon

D.brunnea (Denis and Schiffermuller)

D.rubi (Vieweg)

Xestia c-nigrum (Linnaeus)
Not common

X.triangulum (Hufnagel)

X.baja (Denis and Schiffermuller)

X.castanea (Esper)
Rare 17 August 1976, 14 August 1982, 1 September 1982 (2)

X.sexstrigata (Haworth)
Not common
X.xanthographa (Denis and Schiffermuller)
Naenia typica (Linnaeus)
Uncommon
Eurois occulta (Linnaeus)
Rare 25 August 1977
Cerastis rubricosa (Denis and Schiffermuller)
Uncommon

HADENINAE
Hada nana (Hufnagel)
Uncommon
Mamestra brassicae (Linnaeus)
Melanchra persicariae (Linnaeus)
This species was not recorded in Scotland until 1971 when a single specimen was found in the trap at Falkirk. It was then thought to be a vagrant specimen, but it has since turned up in 1976, 1979 and 1982 in small numbers. Other observers have now noted it in other areas of Central Scotland and it would seem to have established itself.
Lacanobia thalassina (Hufnagel)
L.oleracea (Linnaeus)
L.biren (Goeze)
Uncommon
Ceramica pisi (Linnaeus)
Hecatera bicolorata (Hufnagel)
Hadena rivularis (Fabricus)
Uncommon
H.confusa (Hufnagel)
Not common
H.bicruris (Hufnagel)
Not Common
Cerapteryx graminis (Linnaeus)
Tholera cespitis (Denis and Schiffermuller)
Rare 22 August 1982, 29th August 1982
Panolis flammea (Denis and Schiffermuller)
Uncommon
Orthosis cruda (Denis and Schiffermuller)
Uncommon
O.gracilis (Denis and Schiffermuller)
Rare 15 May 1972, 24 April 1973, 24 March 1977, 17 May 1978, 20 May 1978
O.stabilis (Denis and Schiffermuller)
O.incerta (Hufnagel)

O.gothica (Linnaeus)
O.munda (Denis and Schiffermuller)
Rare 27 April 1982
Mythimna conigera (Denis and Schiffermuller)
M.ferrago (Fabricius)
M.impura (Hubner)
M.pallens (Linnaeus)
M.comma (Linnaeus)

CUCULLIINAE
Cucullia chamomillae (Denis and Schiffermuller)
Not common
C.umbratica (Linnaeus)
Rare 14 July 1976 (2), 22 June 1977, 29 June 1977, 11 June 1978
Cleoceris viminalis (Fabricius)
Dasypolia templi (Thunberg)
Rare 14 Oct, 1966, 28 Sept 1968, 8 April 1971, 4 May 1971, 4 Oct 1971.
Aporophyla lutulenta (Denis and Schiffermuller)
Rare 20 July 1981
A.nigra (Haworth)
Lithomoia solidaginis (Hubner)
Rare 28 July 1980
Xylena vetusta (Hubner)
Uncommon
X.exsoleta (Linnaeus)
Rare 13 Sept 1973, 22 Sept 1981
Allophyes oxycanthae (Linnaeus)
Dichonia aprilina (Linnaeus)
Rare 16 Sept 1971, 19 Sept 1980, 2 Oct 1980, 12 Oct 1980
Dryobotodea eremiat (Fabricius)
Rare 7 Sept 1981, 9 Sept 1982
Blepharita adusta (Esper)
Not common
Antitype chi (Linnaeus)
Not common
Eupsilia transversa (Hufnagel)
Uncommon
Conistra vaccinii (Linnaeus)
Agrochola circellaris (Hufnagel)
A.lota (Clerck)
Not common
A.macilenta (Hubner)
Not common

A.helvola (Linnaeus)
Rare 25 Sept 1977, 7 Sept 1980
A.litura (Linneaus)
A.lychnidia (Denis and Schiffermuller)
Rare 24 Sept 1976
Parastichtis suspecta (Hubner)
Sporadic
Atethmia centrago (Haworth)
Uncommon
Xanthia citrago (Linnaeus)
Not common
X.togata (Esper)
X.icteritia (Hufnagel)
X.gilvago (Denis and Schiffermuller)
First noted in 1976 (probably a first record for central Scotland) this species increased in numbers until 1980 when a total of 8 specimens were found in the M.V. trap at Falkirk. None were recorded in 1981.

ACRONICTINAE
Acronicta leporina (Linnaeus)
Rare 14 June 1969, 19 June 1974
A.psi (Linnaeus)
A.rumicis (Linnaeus)
Cryphia domestica (Hufnagel)
Not common

AMPHIPYRINAE
Amphipyra tragopogonis (Clerck)
Rusina ferruginea (Esper)
Euplexia lucipara (Linnaeus)
Phlogophora meticulosa (Linnaeus)
Sporadic
Ipimorpha subtusa (Denis and Schiffermuller)
Rare 18 Aug 1978
Enargia paleacea (Esper)
Rare 18 Sept 1969
E.ypsillon (Denis and Schiffermuller)
Rare 23 July 1982
Cosmia trapezina (Linnaeus)
Apamea monoglypha (Hufnagel)
A.lithoxylea (Denis and Schiffermuller)
A.crenata (Hufnagel)
A.remissa (Hubner)
A.unanimis (Hubner)
Not common

A.sordens (Hufnagel)
A.ophiogramma (Esper)

Not common

Oligia strigilis (Linneaus) and *O.versicolor* (Borkhausen)
It is not possible to distinguish these two species without examination of the genitalia. An insufficient number have been so examined to give an accurate estimate of the proportion of each in the large numbers observed each year. Both, however appear to be very common.
O.fasciuncula (Haworth)
Mesoligia furuncula (Denis and Schiffermuller)
Not common
M.literosa (Haworth)
Uncommon
Mesapamea secalis (Linnaeus)
Photedes minima (Haworth)
Not common
P.pygmina (Haworth)
Sporadic
Luperina testaca (Denis and Schiffermuller)
Amphipoea crinanensis (Burrows)
Rare 27 Aug 1976, 29 Aug 1978
A.lucens (Freyer)
Hydraecea micacea (Esper)
H.petasitis Doubleday
Rare 25 Aug 1980
Gortyna flavago (Denis and Schiffermuller)
Common until 1972 (10 — 12 each year). Has not been seen since.
Calaena haworthii (Curtis)
Rare 19 Aug 1975, 3 Sept 1981, 11 Sept 1981
C.leucostigma (Hubner)
Noragria typhae (Thunberg)
Rare 3 Sept 1979, 5 Sept 1981, 7 Sept 1981
Rhizedra lutosa (Hubner)
Rare 30 Sept 1971, 15 Oct 1980
Hoplodrina blanda (Denis and Schiffermuller)
Caradrina morpheus (Hufnagel)
C.clavipalpis (Scopoli)

PANTHEINAE
Colocasis coryli (Linnaeus)
Rare 4 June 1973

PLUSIINAE
Diachrysia chrysitis (Linnaeus)

Polychrysia moneta (Fabricius)
Rare 4 at Bonnybridge in 1946
Plusia festucae (Linnaeus)
Not common
Autographa gamma (Linnaeus)
A.pulchrina (Haworth)
A.jota (Linnaeus)
A.bractea (Denis and Schiffermuller)
Not common
Abrostola trigemina (Werneburg)
Rare 12 July 1962
A.triplasia (Linnaeus)

CATOCALINAE
Calistege mi (Clerck)

OPHIDERINAE
Scoliopteryx libatrix (Linnaeus)
Rare 4 Sept 1968, 27 May 1970 (2), 14 Sept 1972

HYPENINAE
Hypena proboscidalis (Linnaeus)
Polypogen tarsipennalis (Treitschke)
Sporadic
P.nemoralis (Fabricus)

BOTANICAL REMAINS OF EDIBLE PLANTS FROM IRON AGE BROCH, FAIRY KNOWE, BUCHLYVIE, STIRLING

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INTRODUCTION

In 1978, Lorna Main reported in these pages on the archaeological excavation at Fairy Knowe, Buchlyvie. I helped in this as a student and have since, as a specialist, had the opportunity to study the botanical remains collected during the excavation. Some of the main findings of this research are presented here, although fuller details will be published. (Main, in preparation).

THE SITE

The site (National Grid reference NS 586 943) consists of the remains of a broch situated on a small boulder-clay mound ("Fairy Knowe") overlooking the flat carselands of the Forth Valley. Although there were two phases of construction (an early timber roundhouse and a later stone-built broch), occupation was probably continuous, the roundhouse being occupied during the first century AD and the broch, constructed in the latter half of that century, being occupied until about 200 AD.

THE BOTANICAL REMAINS

Almost all of the botanical remains have survived due to being charred, and were recovered mainly from occupation levels (floor composed of soil, charcoal and other debris) and hearths. To fully interpret the significance of these plant remains, several things need to be known apart from their identification. First, their modern ecology is important, although it must be remembered that the behaviour of plants may change with time. Secondly, it is useful to know how these plants were used in the past in Britain and, in some cases at present, in other societies. This forms the "ethnographic record" to which reference will be made later. Finally, the plant remains must be considered as an assemblage rather than as individual species. In the discussion which follows, the plants represented at Fairy Knowe are described briefly, and some aspects of their past and present ecology and use will be discussed. The details of identification will be published in the full excavation report. Plant nomenclature used follows Clapham et al (1981) and Hubbard (1968).

THE CEREALS

By far the most abundant remains are those of barley *(Hordeum)* mostly being caryopses (grains). The remains are probably lax-eared six-row barley *(H.vulgare)*, a primitive barley representing "bere" barley and formerly known by the misnomer "four-row barley". Most of the barley remains at Buchlyvie occur in features associated with the broch, the bulk being from one sample. There are also a few remains from the pre-broch roundhouse stage. Several other cereals are also present, all from the broch, and all in very small quantities. They are emner wheat *(Triticum dicoccum)* a primitive wheat no longer cultivated in Britain, club or bread wheat *(T.compactum* or *aestivum)*, bristle or black oat *(Avena strigosa)* and the common wild oat *(A.fatua)* a possible weed.

Barley is an early-maturing grain, well suited to the cool wet climate of north and west Britain (Bland 1971), and is better adapted than other cereals to grow at the fringes of agriculture (Harlan 1976). Bere barley grows on poorer soils and at higher elevations than any other barley variety. It was previously cultivated throughout the uplands of Wales and Scotland, but at present is only cultivated on some western and northern Isles. In contrast, wheat cultivation in Scotland is limited by the climate, only the east coast providing the adequate conditions of lower rainfall and higher sunshine, and by the distribution of suitably fertile soils.

Of the oats present at Fairy Knowe, bristle oat is a cultivated oat, grown extensively in marginal sites on the poorest soil during historical times throughout Scotland and Wales. It is now grown as a crop only in the northern and western Isles. Where it still occurs on the Scottish mainland, it grows as a weed, often in barley crops. Wild oat, on the other hand, has probably never been cultivated in Britain. It is a common, and often troublesome, weed of cereal crops. Interestingly, in California where the wild oat has successfully naturalised during the last few centuries, Indians collect the grain to use as bread corn (Sturtevant 1919). The wild oat may possibly have been an acceptable weed in Iron Age Britain.

THE WEEDS

A limited range of weed fruits and seeds were recorded, mostly in the barley-rich sample. These were fat hen (*Chenopodium album*), black bindweed (*Fallopia convolvulus*), goosegrass (*Galium aprine*), knotgrass (*Polygonum aviculare* agg.), pale persicaria (*P. lapathifolium*), wild radish (*Raphanus raphanistrum*), sheep's sorrel (*Rumex acetosella*), red-veined dock (*R. sanguineus*), chickweed (*Stellaria media*) and stinging nettle (*Urtica dioica*). The majority of these are common weeds of cultivated or waste ground, and where they are found in archaeological remains, are generally regarded as weed contaminants of cereal crops. The seeds of *Raphanus raphanistrum* are enclosed in pod segments which, being similar in size to cereal grains, are frequently not removed by sieving or winnowing of cereal crops. The others tend to be small seeds, and although hand sorting of grain can be efficient (Hillman 1981), they may have easily been missed. Many of these weeds have in the past been cultivated or collected from the wild throughout the world and used as pot-herbs, salad or green vegetables, or as food flavouring, (Sturtevant 1919). It is possible that these weeds were used as food in Iron Age Britain.

INTERPRETATION OF THE CEREAL AND WEED REMAINS

Although 25 samples from various types of features at the site were examined, only one had sufficient grain, seeds and other remains for detailed analysis. To understand the full range of the agricultural pattern at an archaeological site, it is necessary to examine botanical samples from as many structures and periods represented at the site as possible (Hillman 1981). Nevertheless, some detail of the agricultural patterns at Fairy Knowe can be deduced from the evidence available.

The large amounts of barley, together with the relative scarcity of other cereals, suggests that barley was an important, if not principal crop used by the broch occupants. The small amount of wheat remains suggests that it was a minor crop or contaminant of local barley fields. Likewise, the remains of bristle and common wild oat may represent weeds of barley, but given the former widespread cultivation of bristle oat in Scotland, it is possible that the grain represents the cultivation of bristle oat at Fairy Knowe.

Perhaps the most important outcome of this analysis is that beyond merely providing a species list of cultivated plants and their weeds at an Iron Age site, it is possible to make certain comments regarding the processing of these cultivated plants. Most of the plant remains are from only one grain-rich sample, and therefore only represent one event, such as an accidental burning of grain during processing. Hillman (1981) has recorded the details of cereal cultivation and processing in Turkey, paying particular attention to the possible archaeological record resulting from the various stages involved. He studied an area in which the cereals grown and the tools and methods used are either the same or similar to those known for the Iron Age in Britain and Europe. His ethnographic model for cereal processing is most useful in the interpretation of fossil plant remains. Comparison of the range in the grain-rich sample at Fairy Knowe with assemblages recorded from various stages during the processing of free-threshing cereals such as barley (Hillman 1981 figure 6), suggests that the sample represents a stage after threshing and winnowing. This could be either between the first sieving, in which a medium-coarse sieve is used to remove large fragments such as straw nodes and weed heads, and the second sieving, in which a finer 'wheat sieve' is used to remove fine material such as immature grain and most weed seeds, or after both sievings. Such a stage occurs immediately prior to kiln-drying, when the grain is dried to avoid spoilage during bulk grain storage, and the sample analysed probably represents the accidential burning of grain during kiln drying.

The presence of an assemblage representing this stage suggests that the grain was locally processed, and therefore, probably cultivated nearby, and was not imported to this site. This conclusion is important since, although it is entirely reasonable to expect both on social and ecological grounds that the local Iron Age communities were growing and processing their own cereals, there has been little direct evidence for this happening in central Scotland (Boyd forthcoming). Although fossil cereal evidence from other Iron Age and Roman sites in central Scotland (Dickson and Dickson forthcoming, Jessen and Helbaek 1944, Dimbleby and Sheldon 1977–78, Robinson 1983) shows that various cereals were present at these sites, it does not indicate that they were necessarily grown and processed locally. Indeed, at some sites e.g. Bearsden Roman fort (Dickson and Dickson forthcoming) cereal grain was probably imported, possibly from other regions of Britain.

THE ARCHAEOLOGICAL RECORD OF CEREALS

How do these records of cereals and their weeds fit into the present archaeological record? Barley is the most commonly occurring cereal at Scottish Iron Age sites, and six-row barley is recorded at Iron Age sites throughout Scotland. Four sites in central Scotland are of particular interest. At the nearby broch of Leckie Dun (NS 688 956), several hundred grains were recorded together with a range of weeds seeds similar to that recorded at Fairy Knowe (Dickson, forthcoming a, and pers. comm.). At the native Iron Age site at Camelon, Falkirk (NS 863 812), grain is found which probably all represents bere barley (Dimbleby and Sheldon 1977–78). Further afield, six-row barley is recorded in a small quantity at Balloch hillfort, Kintyre (NR 677 176) (Dickson in press) and a larger amount at Dun Mor Vaul, Tiree (NM 046 493) (MacKie 1974).

The prehistoric status of wheat in Scotland is somewhat less clear. Since many of the early records of wheat are associated with Roman sites (Jessen and Helbaek 1944) there may be some doubt as to whether wheat was grown in Scotland or imported. However, there is sufficient evidence for the presence of emmer bread and club wheat at various sites throughout Scotland since at least the Bronze Age, and given the widespread past presence of wheat in Scotland, and past climatic differences, it is possible that wheat was grown during the Scottish Iron Age, albeit as a minor crop.

Oats present another problem. Despite its former widespread historical presence in Scotland, bristle oat is poorly represented in the archaeological record, the only definite native Iron Age record being on Orkney (Dickson forthcoming b). There are also two records from Roman sites of the Antonine Wall, in one of which identification is uncertain (Jessen and Helbaek 1944). The common wild oat is likewise poorly represented, the only definite Iron Age record being from a broch in Caithness (Dickson 1979).

OTHER EDIBLE PLANTS

Another edible plant represented at Fairy Knowe is hazel (*Corylus avellana*). The distinctive nut fragments are, with the exception of barley and oat remains, the most abundant plant remains. They are found associated with both broch and pre-broch remains and hazel nuts may therefore have been an important food source throughout this site's occupation. The kernels provide a convenient food, which can either be eaten raw or ground into a flour for baking, and have been used to provide edible oil (Sturtevant 1919). Although hazel nuts are commonly found at archaeological sites throughout Britain and probably have been an important food source from the earliest times, there are few other records of hazel nuts at Scottish Iron Age sites. At Fairy Knowe, it is probable that the nuts were collected in the wild, and although it is unlikely that hazel was deliberately planted to provide food, it is possible that it was managed by burning or coppicing, to provide increases in the crop of nuts.

One final plant to be discussed is *Allium ursinum* (ramsons or wild garlic). Several carbonized bulbous roots of this plant were found together in an occupation layer. Ramsons has an historical record from Europe and northern Asia of use as a food, both as a green and salad vegetable and as a food flavouring, and its relative *A. sativum* (garlic) has a long folk history of use in medicine and religion, as well as a food (Sturtevant 1919). The ramsons bulbs at Fairy Knowe may therefore have represented food collected in the wild, either being waste from the use of its leaves, or more probably, the accidental loss of bulbs prior to use. It might be speculated that these local plants may have been used as a substitute for garlic (which does not grow naturally in the wild in this area) in some medicinal or religious activity.

CONCLUSION

The results indicate that, even with relatively sparse evidence, there is much to be learned from the study of botanical remains from archaeological sites. In this case it is possible to recognise elements of the agriculture practice at the site, and to illustrate the probable presence of wild plants in the Iron Age diet. The conclusions reached provide only a fraction of the entire picture reflecting a small and possibly unrepresentative part of the complex, but vitally important, system of food production which supported the life of the Iron Age inhabitants of Fairy Knowe.

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COAL MINING AT CULROSS: 16–17th CENTURIES

Ian Bowman

One of the wonders of Scotland in the late 16th and early 17th centuries was the colliery of Sir George Bruce at Culross on the shores of the Forth at the south-western end of Fife, which in the 16th century was part of Perthshire. Its spectacular features — an 'Egyptian Wheel' for deep drainage and a 'Moat Pit' set in an artificial island below high water mark — aroused considerable interest, bringing people from far afield to view them. John Taylor, the 17th century 'Water Poet' from London, included the mine in his 'Pennilesse Pilgrimage' in Scotland. King James VI is said to have visited it. Neighbouring coal masters, particularly the first Earl of Wemyss, took up some of Bruce's technical ideas with considerable success, and they were passed on to mining areas outwith the Forth Valley. These ideas, some of them well in advance of their time, made an important contribution to Scottish mining in various fields — in drainage, in ventilation, in the extraction of coal at considerably lower levels than had been customary in Scotland; and in the field of labour relations, improving the condition of the colliers and their families. The working of Culross Colliery by Sir George Bruce was not only an important influence in the development of Scottish coal mining, it was also a contributory factor in the broader economic development of the Forth Valley in the 17th century. Around the Colliery he built an extensive industrial complex, with salt making on a considerable scale, iron working, glass making and a vigorous export trade. His ships carried coal and salt not only from Culross, but from Bo'ness, and possibly Airth, to ports on the east coast of England, to London and to the Continent, with which they traded extensively. The Calendar of Scottish Papers has some interesting references to happenings in this trade, including the plundering of the FALCON and the JESUS in Lowestoft Roads in 1583 (VI 431 and 432); reprisal for damage to salt in one of George Bruce's ships by John Keler, Englishman, in 1593 (XI 156); the capture of Bruce's ship BRUCE by the English JULIEN and the destruction of her cargo of wine from Portugal in 1598 (XIII 270). There is evidence of trade with Scandinavian and Baltic states also. Culross Colliery was an important feature in the minor industrial revolution that changed the Forth Valley in the 17th century, when the restraint on the exploitation of its material resources exercised by the landholding religious establishments had been withdrawn, allowing the coal and salt industries to build up with associated industries developing around them.

The Colliery lay west of the town, just beyond the hamlet known as Blairburn. It had two points of entry and exit, one on the land below the hill on which stands Dunimarle Castle and one on the lowest part of the foreshore roughly due south of the other entrance. The two were connected by an underground road, probably about 250 feet below the surface. Side roads ran out from this main road into the coal. Latterly the workings seem to have extended eastwards under the foreshore, with some new shafts being sunk to facilitate the coal getting. These, however, must have been subsidiary sections. The most important workings were centered on the main underground road.

George Bruce belonged to a collateral branch of the family descended from King Robert the Bruce. He was the third son of Edward Bruce of Blairhall, the other sons being Robert and Edward. His father acquired some of the land of Blairhall from the Cistercian Monastery at Culross in 1540 (Laing Charters 78). At the time the Abbot of Culross was John Colville. His brother William was Commendator of the Monastery, looking after the estates and other property (ibid 77). He seems to have managed them to the advantage of the Colville family. The Laing Charters record a feu of February 1540 from William and John Colville to their brother-german, Robert Colville, and Margaret Skougall and heirs, of a salt pan and land to build a storehouse for salt. Also 'license to dig coals from the granter's coal-heughs, and to dig new coal-heughs for the upkeep of the pan.' The feu was 5 marks yearly. Several other similar feus of salt pans and coal-heughs went to various members of the Colville family (ibid 77-8). Such feuing was a fairly common practice at the time with respect to Church lands. In the case of Culross, it must have benefited both the ecclesiastical establishment of the Abbot and also the members of his family, to their mutual satisfaction. It did not, however, make for efficient commercial exploitation of the resources; indeed, the Church does not appear to have thought of coal-mining as a profit-making industry. A coal concession granted to the Abbot and monks of Dunfermline carried a condition that the coal which they acquired should be for their own use alone (Barbe 1919 196). The use of coal for aims-giving in some Scottish establishments is referred to by Aeneas Silvius in *De Europa*, and Hector Boece stated that it was 'richt profitable for operation of smithis' (ibid 198 and 200). None of this would call for coal production on a large scale. Under the landlordship of Culross Abbey salt making and coal mining were done on a small scale only, by local salters and colliers taking sub-leases from the feuers.

The connection of Edward Bruce with the Colville family has not been clearly established, but a lease deed given by Alexander Colville to George Bruce refers to him as 'our cousin', which suggests some sort of family relationship, or at least a close friendship. Edward Bruce had a house in Culross; his sons Edward and George are believed to have been born there. Edward, who was to become Lord Kinloss, is thought to have been born in 1542, so that George is unlikely to have been born before

1544. As he died in 1625 it is more likely to have been in the 1550s. So far no record of his birth has been traced. Nothing is known of his early years, but his work with the Colliery suggests that he had considerable knowledge of continental mining techniques and technology. This is borne out by the preamble to the lease of the Colliery which he was given in 1575 by Alexander Colville, at that time Commendator. It is quoted by Archibald Cochrane, 9th Earl of Dundonald, and by others, who probably used his quotation (Dundonald 1793). The preamble reads as follows

> 'To our worthy friend and cousin George Bruce, for the great regard we bear him, for the special care he had of our affairs when we were abroad in France, for his great knowledge and skill in machinery such like as no other man has in these days; and for his being the likeliest person to re-establish again the Colliery of Culross, which has long been in desuetude, insomuch that we have neither large nor small coal for our own housefire.'

Colville obviously had a high opinion of Bruce's technical knowledge. But this was only one facet of Bruce's character and personality. With his technical expertise he combined considerable business acumen. He was an entrepreneur of some stature. His strong room in the 'Palace' at Culross, where he lived in the latter part of his life, with its heavy stone vaulting and massive door, testifies to a man who 'thought big'.

In addition to his industrial and business activities, Bruce was involved in public service. He became a member of the Scottish Parliament in 1593 and served as such for many years. He was one of the Commissioners who arranged the details of the Union of the Crowns in 1603. Other offices held by him were Lord of the Privy Council and Exchequer and Commissioner of Justiciary. He served on Commissions appointed to set out marks and lights in the Firth of Forth; to control the export of bullion from Scotland; to standardise weights and measures; to investigate the condition of mining in the Water of Forth; to report on the export of coal from Scotland; to promote the manufacture of Scottish glass; to investigate the local government of Dundee. He was appointed Overseer of the Royal Mines. In 1602 he bought from Lindsay of Byres the Barony of Carnock and thereafter styled himself Bruce of Carnock. About 1610 he was knighted and became Sir George Bruce of Carnock. He was a major benefactor of Culross, bringing prosperity to the town and having it raised to the status of Royal Burgh. He improved the social and domestic conditions of his employees. He left on the town an imprint of his personality which is still felt. His effigy on the fine baroque tomb provided by his sons in Culross Abbey suggests a man of firm but kindly character. It is the only representation of him extant.

But among his varied activities his successful development of the Colliery must be given first place. It is in the sphere of coal mining that his main importance lies.

When Bruce took his lease of Culross Colliery in 1575 there was a rapidly increasing demand for Scots coal, both at home and abroad. In the early part of the century the indiscriminate use of Scotland's timber resources had created such a shortage of wood that in the middle of the century, as recorded in Acts of the Scottish Parliament, legislation was passed rigorously controlling the cutting down of trees (ibid II, 33, 1555 and III, 27, 1567). This made people turn to coal for fuel and greatly increased the home demand. At the same time the loosening of the Church's control over much of Scotland's natural resources, brought about by the Reformation, had resulted in an expansion of trading with England and the Continent. This was encouraged by James VI. Scottish great coal — 'charbon d'ecosse' — was much in demand in the Low Countries and was considered in London to be the best coal for the manufacture of glass. As the foreign market grew there was so much export of coal that there was apprehension in the burghs and in Government that there would not be enough for home consumption. Legislation was passed prohibiting export without special permission (ibid II, 22, 1563 and III, 28, 1579). The coal owners, however, found ways of evading the prohibition. For instance, coal was used as ballast in ships returning to England or the Continent after discharging their cargoes in the Forth ports (ibid II, 22, 1563). But a much more effective curb than legislation on the export of coal lay in the primitive methods of coal getting, which limited pit depths, so that the life of any one sinking was short and necessitated frequent changes. Early methods of coal working in Scotland were (1) the bell pit, in which a short vertical shaft was sunk to the coal and the shaft bottom was 'belled out' as far as it was possible to extract the coal with safety; (2) the pit and adit method, in which the shaft was sunk onto the coal and a drainage tunnel was driven below the workings to keep them clear of water and to help ventilation; (3) the picturesquely-named 'ingaun ee', which was simply an adit driven into the coal and worked for as far as air was available. These methods were suitable for shallow workings only, which were quickly exhausted. Steadily growing demand called for exploitation of the deeper seams: this raised problems of surveying, drainage, ventilation, haulage and lifting. Scottish mining techniques in the mid-16th century were crude and limited and did not compare with those which had been developed in Germany and elsewhere on the Continent, where wheels driven by water or animal power were used for drainage mines and raising coal, crude fans were employed to help ventilation and the art of surveying had been developed to a fair extent. James V had tried to introduce some of these methods by importing German miners, but their influence seems to have been negligible. It was George Bruce who showed the Scottish miners the way in his development of the Colliery at Culross.

The coal at Culross belonged to the seam known as the Janet Peat or Jenny Pate, in the Upper Limestone Group. This is the thickest coal in the Group, the seam varying from five to nine feet in thickness. Sometimes it occurs in two leaves. It runs from three to four fathoms below the Jenny Pate or Calmy Limestone. The coal is of inferior quality on account of the amount of iron pyrites in it, but it is nonetheless usable in a variety of ways, and was well thought of in Bruce's day.

At Culross the seam ran out south-westward from under the moor above the town, rising in an anticline to five fathoms below ground level. At Blairburn, the hamlet at the west end of the town, it hit a fault which threw it a little north and west. It maintained its level for a short distance, running toward the shore. Under the shore it dropped to about 40 fathoms, going down fairly steeply. At the extremity of the low tide level, known as the mussel scalp from the mussel-covered outcrops of rock which bordered it, it swung round towards the fault and when it hit it was thrown slightly north and east again, coming up to the higher level as it ran inland under Culross town and then falling gradually on the east side of the anticline.

The coal at the higher levels is said to have been worked by the monks of the Monastery, but it is more likely that the work was done by colliers employed under the supervision of the monks or of the Colville family and other feuers of the Abbey lands. There is, unfortunately, no detailed record to show where the workings were, but the probability is that they were all on the east side of the fault. At Blairburn, where the seam hit the fault, it was crossed by the Dean Burn and there could have been drainage problems. Whether any working was done under the town area is not clear. When the group of houses in Culross known as Macdonald's Land was being restored about 1970 old mine workings were found underneath them. They were thought to date from the mid-16th century, but the matter is uncertain. By the time that George Bruce took over the Colliery in 1575 working had been abandoned for some time. As the preamble to his lease has it, '... the Colliery of Culross which has long been in desuetude..' From the development of the workings under Bruce it is reasonable to assume that he was chiefly concerned with that part of the seam which lay to the west of the fault.

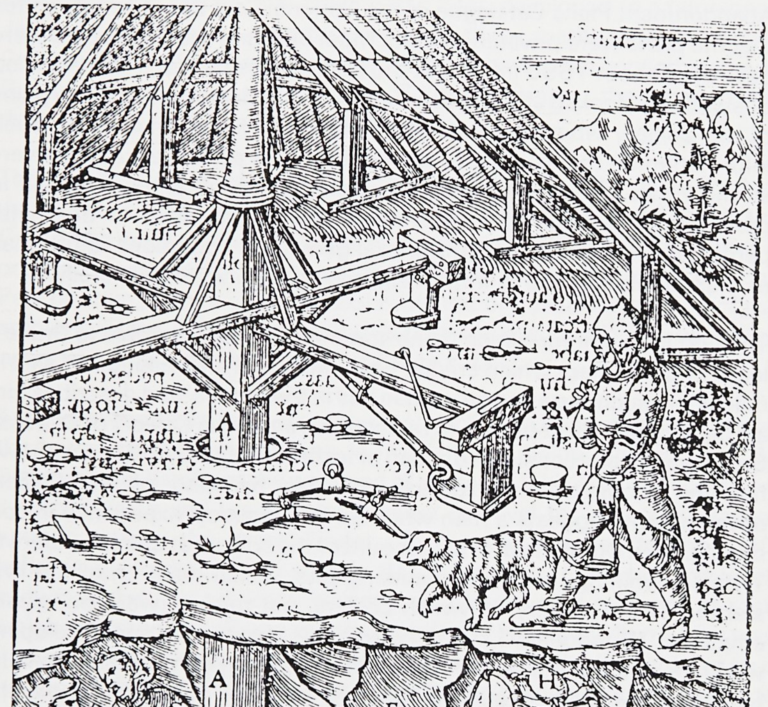
No plans of the workings of Bruce's Colliery are extant. The

Abandonment Plans Catalogue of the National Coal Board simply states that the plans were privately owned. Most of Bruce's family papers were destroyed about 1650 in a fire at the Edinburgh office of a lawyer called Boswell, who looked after the family affairs. It is presumed that any plans of the Colliery which existed were lost in the fire. Nonetheless, such information on the working of the Colliery as is available suggests very strongly that its development was carefully planned and carried out in pre-arranged stages. The innovations were introduced to deal with particular problems arising from local geological conditions rather than as experiments aimed at improving mining techniques generally.

The first item of information is the statement in the preamble to Bruce's lease of the Colliery which credits him with 'great knowledge and skill in machinery such like as no other man has in these days' and describes him as 'being the likeliest person to re-establish again the Colliery of Culross'. Bruce was clearly considered a man of technical expertise. It is not known how he acquired this expertise, but his handling of the Colliery development suggests a man who had had practical experience in coal mining. Lord Dundonald, in his account of the colliers at Culross, refers to 'a deal of mining, boring and sinking pits, which went on at the first starting of the colliery, in which colliers, not miners, were principally employed' (Dundonald 1793). If Bruce was able to start and develop his workings without the skilled help of miners, using only ordinary colliers, he must have had great confidence in his own ability to handle the operation. No-one lacking in practical experience would have been able to justify this confidence by results, as Bruce did. Where he obtained his experience is not known, but it is unlikely to have been in Scotland or in England, as neither was advanced in mining at that time. Germany is the most likely place, although there is no clear evidence that Bruce spent any time in that country. It is possible that he derived some of his ideas from the book *De Re Metallica* by Agricola (1556). It gives a fairly detailed description of mining operations on the Continent, with illustrations of machinery and methods similar to those employed by Bruce. In some of the drawings of underground workings the ground is cut away to show parts of the machinery which would not be visible from the surface. There is a section on surveying preliminary to sinking pits which shows that even in the 16th century a good deal of information about seams of coal was obtained from boring. Dundonald's reference to boring suggests a preliminary survey of the area.

The evidence which indicates a carefully surveyed and planned operation comes from the account of the mine by John Taylor, the 'Water Poet', who visited it in 1618. Taylor says

> 'The mine hath two wayes into it, the one by sea and the other



Horse gin (horse unyoked) — for raising water from a mine
Agricola Bk.6 p.152

Site of Castlehill Pit, Culross

> by land... Besides, the mine is most artificially cut like an arch or a vault all that great length, with many nookes and by-ways; and it is so made that a man may walk upright in the most places, both in and out' (Taylor 1630).

This suggests a planned operation, cut directly through the rock which lay on the line between the two pit bottoms, with side roads giving onto the coal. Such an operation must have been dependent upon a preliminary survey. Further evidence of a survey is found in Taylor's remarks about the construction of the second pit, known as the Moat Pit.

> 'They did dig forty foot downe right into and through a rocke. At last they found that which they expected, which was sea-cole...'

The operation was obviously not a random one. The men who were digging knew what they were heading for. This also indicates a preliminary survey.

In the absence of records it cannot be stated with certainty how the development was carried out, but there can be little doubt that the starting point was near Blairburn, where the Jenny Pate seam struck the fault and was thrown north and west below the Dean Burn. The Geological Survey map shows an old pit shaft in this area — the only one marked as such (Geological Survey of Scotland 1921 Fifeshire, Sheet XXXVII SE). Traces of this shaft can be seen on the lower slopes of the hillside to the east of Dunimarle Castle. John Cummings in 1705 spoke of a 'sink' (pit) in the Castlehills lands called 'the bread pot' (Elgin Archives). It is almost certain that he was referring to this pit. For convenience in identifying it, it is now referred to as the Castlehill Pit. The remains of the pithead would be an interesting subject for excavation.

The coal for some distance on the west side of the fault was only about five fathoms below ground level. Bruce could have worked it by an 'ingaun ee' or adit, and this is perhaps what he did while carrying out a survey of the coal below the foreshore. It would ensure that the Colliery was in production fairly soon after the taking of the lease, while the main scheme for development was being planned, its tactics being largely determined by the geological formation of the area. Central to this development was the driving of a main road through rock from the pit bottom at Castlehill to the lowest point on the foreshore where the seam turned to run back under the land. The making of this road with the primitive instruments available at the time must have been a major operation. Its length was at least half a mile, taken in a straight line. The depth must have been more than 40 fathoms, to allow for drainage and haulage from the deepest workings. Taylor's statement that a man could walk upright in most places indicates a road of considerable dimensions, as mine roads went at that time. The fact of its being driven through rock suggests that Bruce aimed at having its roof as secure as possible, without having to rely too much on roof supports. It must have taken some years to complete the road, particularly if there was concurrent development of side roads into the coal. Bruce's work force must have been of a fair size. Taylor in his account says that 'Many poore people are there set on work, which otherwise through want of employment would perish...' By the time that Taylor visited the mine, Bruce was legally entitled to press into his service vagabonds and sturdy beggars (ASP 1607 7). It is possible that his employment of 'poore people' was not as altruistic as Taylor suggests, but there is evidence that Bruce was interested in the welfare of his employees and that he used local rather than casual labour — although latterly he had at least one Englishman working at the Colliery (Shearer 1951 p126) and it is possible that by that time he was bringing in outside labour. In 1607, however, in a submission to the Privy Council about damage to his works, its Records quote

> '... their is an infinite number of puir creatures quhois onlie moyane and maintenance dependis upoun the saidis workis, and without the quhilkis they would have no meanis to sustene and interteny themselfis' (RPC VII 1607 189).

Dundonald (1793) states that

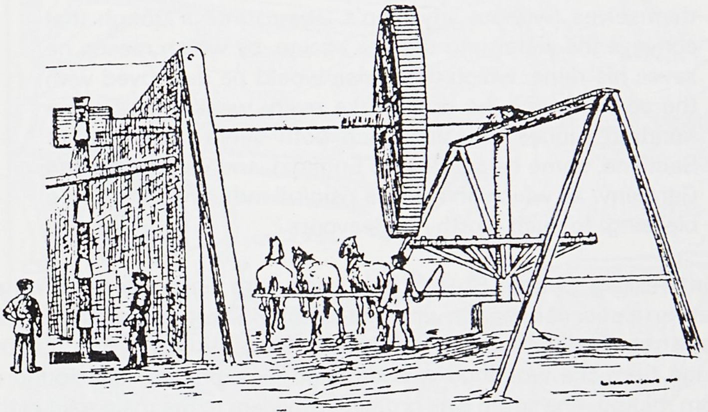
> 'It is but justice to the colliers formerly employed at Culross colliery to say that they, in contradistinction to other colliers, were in general steady, sober and men of principle, well-clothed, neat in their persons, and well supplied with household furniture. This favourable alteration in their conduct and manners is to be ascribed to several causes:
>
> 1. To a deal of mining, boring and sinking pits, which went on at the first starting of the colliery, in which colliers, not miners, were principally employed. By this means their wives were exempted from the drudgery of bearing coals in the pits, and by staying at home contracted a habit of domestic attention and care of their families, while the husbands, learning to be miners, adopted their manners, and who in general are a very orderly and sober set of men.
>
> 2. Few or no stranger colliers were employed at the works, the colliers belonging to the colliery being sufficient to raise

> the quantity of coal required for sale.
>
> 3. The colliers were not paid their full wages weekly, or once a fortnight, as is the practice in other collieries. They were paid each fortnight as much as support their families. The balance or arrears was paid once in 3 or 4 months. This mode of paying made them more economical.'

Dundonald's account of the colliers suggests a humane and enlightened employer, interested in the welfare of his employees. It is not clear whether the exemption of women from the work of coal bearing applied only to the wives of those colliers who were doing miners' work, or whether there was a general exclusion of women from the pits. Although coal bearing was generally done by women in the Fife mines, it is possible that Bruce discouraged this practice in view of the improved circumstances experienced by the colliers employed as miners. It was in the interest of the efficient working of the Colliery to have a well-ordered, sober community of workers.

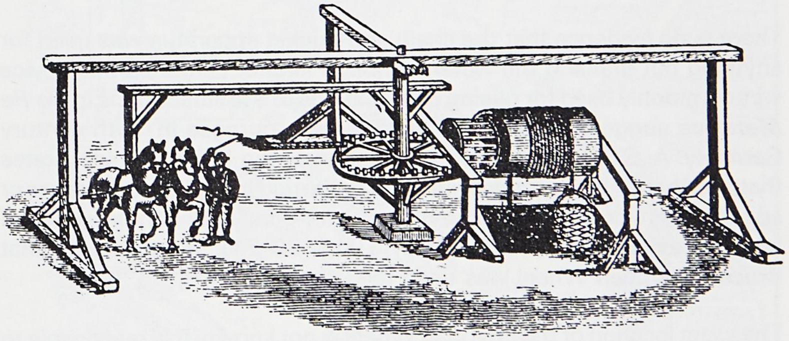
There is nothing in the remains of the Castlehill pithead to indicate whether ingress was by an 'ingaun ee' or by a pit shaft. Possibly both were used, the 'ingaun ee' for the higher coal, the shaft for the lower. Cummings refers to a 'sink', which was usually intended to mean a shaft. This might have been more appropriate for the depth involved and the geological formation. It can however, be accepted that it was from the Castlehill entrance that the workings were advanced southward to the bottom of the foreshore. As they advanced, side roads or bords would be driven upwards into the coal, so that it could be brought down more easily to the main road, for transport to the pit bottom. In this operation the two basic problems of drainage and ventilation must have become increasingly acute as the workings went forward. Bruce dealt with them both together by the installation of an 'Egyptian Wheel', an innovation to Scottish mining which made a great impression on the coal masters of the Forth Valley and which was to become a common feature of Scottish mines in the era before the steam engine and for some time thereafter. The device was a very ancient one, probably developed first in the Middle East in connection with irrigation — hence the name. It consisted of a horizontal wheel driven by horses and geared to a vertical wheel on whose axle was an endless chain of buckets going down into the water and scooping it up. John Taylor (1630) described the device as follows

> 'The sea at certain places doth leake or soak into the mine, which, by the industry of Sir George Bruce, is all conveyed to one well neare the land, where he hath a device like a horse-



Egyptian Wheel —

Bruce's chain and bucket system for water pumping 1600 — 1625



Horse-Gin or Horse-Engine for raising coal in shallow shafts (Barrowman 1886)

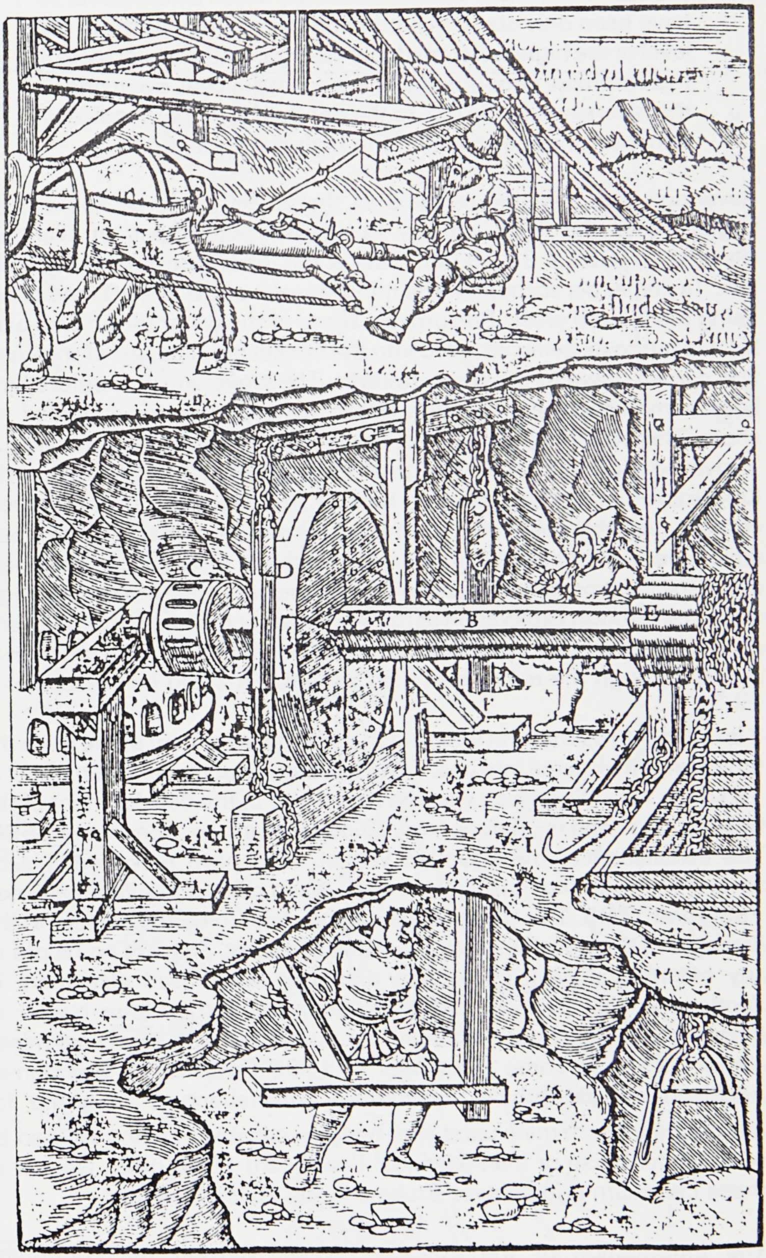
> mill, that with three horses and a great chain of iron, going downeward many fadomes, with thirty-six buckets fastened to the chaine, of which eighteene go down still to be filled, and eighteene ascend up to be emptied, which do emptie themselves (without any man's labour) into a trough that conveys the water into the sea againe, by which means he saves his mine, which otherwise would be destroyed with the sea; besides, he doth make every weeke ninety or a hundred tunnes of salt, which both serve most part of Scotland, some he sends into England, and very much into Germany; all which shows the painfull industry, with God's blessing, to such worthy endeavours.'

It is interesting to note Bruce's salt trade with Germany, which may indicate an earlier connection with that country. The interpretation of this passage from Taylor's account is that Bruce had a sump into which all the drainage from the workings was directed — a practice still found in modern mining. The sump was probably adjacent to the main road in the mine and would be below the level of the coal workings, so that the water from the coal faces could run down into it along channels made for the purpose. A shaft was sunk onto the sump and the chain of buckets operated in this shaft, the wheel being set directly above it. The shaft brought air down into the road. As it reached a lower level than the pit bottom at Castlehill, it was possible to have a through draught in the road, with the air moving down one shaft and up the other according to the season of the year. It would also be possible to have some ventilation at the coal workings.

There is no evidence that the chain and bucket apparatus was used for anything but draining the water, although in later centuries this device was commonly used for raising coal, and one of the illustrations in *De Re Metallica* suggests that it was used for this purpose in 16th century Germany. A. S. Cunningham, the historian of the Fife coalfields, states that coal in the Fife mines continued to be carried in baskets up ladders or spiral stairs long after horse-gins, water-gins and windlasses had become established (Cunningham 1913 20-21). It is unlikely that Bruce's Egyptian Wheel was used to raise coal.

The exact location of the Egyptian Wheel is not known. It is reasonable to suppose that it was on the line between the Castlehill Pit and the turning point of the seam at the lowest part of the foreshore. Dundonald (1793) states that

> 'Sir George Bruce erected machinery consisting of the Egyptian Wheel, commonly called chain and bucket, to drain



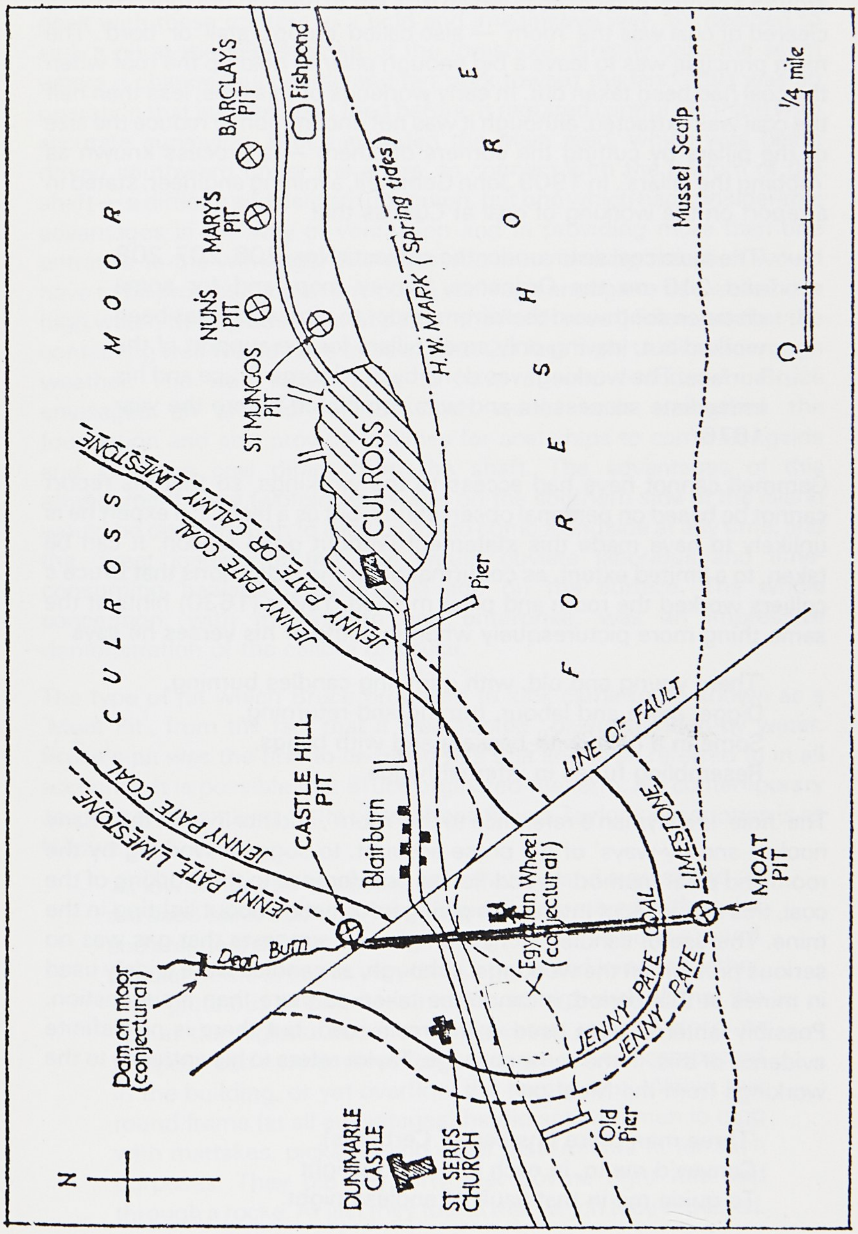
Horse gin — from Agricola Bk.6 p.125

> the coal to the dip of the old workings, which since appear to have been only about five perpendicular fathoms below the level of the high-water mark. Sir George, by the assistance of this machine, wrought one of the seams of coal, upon one of the reversions of the dip, to the depth of forty perpendicular fathoms, under and within the high-water mark.'

Beveridge says that the remains of the wheel could be seen at the beginning of the 19th century in an old 'bucket pat' at Blairburn (Beveridge 1885 II 311-312). 'Bucket pat' was a local name for a salt pan. Taylor, in his account of the mine, speaks of 90 to 100 tons of salt being made each week. Presumably some of the water raised was used for this purpose, being emptied into the bucket pat. The rest of the water was carried down to the sea in troughs. The wheel must therefore have been somewhere near the high water mark, on the upper part of the shore. This would agree with Taylor's statement that the water was all 'conveyed to one well neare the land.' The embankment which carries the Kincardine-Dunfermline railway, built at the beginning of the present century, probably obliterated the bucket pat and any remains of the wheel which were extant at the time. In the absence of any clear statement about the location of the Egyptian Wheel, the only hope of determining it would be through exploration of the main road of the mine, a difficult and dangerous operation, but one which could be rewarding if the problem of access through the remains of the Castlehill Pit could be overcome.

It is difficult to estimate at what stage in the development of the mine the Egyptian Wheel came into use. Taylor states that at the time of his visit in 1618 the Moat Pit, which was the next stage in the development of the Colliery, had been in operation for 28 or 29 years, i.e. from about 1590. The installation of the Egyptian Wheel must have preceded this by several years, so that it is likely to have taken place some time between 1580 and 1585. This gives Bruce a good claim to be the pioneer in the drainage of deep workings by mechanical means. There is no record of any mechanical device for deep drainage being used elsewhere in Scotland at that period. It was not until 1595 that John Napier of Merchiston worked out machinery for pumping water from coal mines (Arnot 1955 3). Three years later in 1598 Gavin Smith and James Aitchison are said to have invented an 'artificial engine' or 'pomp' for raising water from mines and coal-heughs, capable of being worked by wind, water horse or man (National Coal Board 1958 p42). Neither of these can claim priority over Bruce and his Egyptian Wheel.

The introduction of the Egyptian Wheel allowed the continuing development of the mine further under the shore, with the main road being driven southward through the rock and side roads running up from



Plan of Culross and the Colliery

it to the coal. The method of working the coal must have been an early form of 'room and pillar', whereby coal was extracted from a given area around a central pillar of coal, which was left to hold up the roof. The area cleared of coal was the 'room' — also called 'stoop', 'stall' or 'bord'. The main principle was to leave a big enough pillar to hold up the roof when the coal had been taken out. In early workings of this type, less than half the coal was extracted, although it was not uncommon to reduce the size of the pillars by cutting the corners off them — a process known as 'robbing the pillars'. In 1909 John Gemmell, a mining engineer, stated in a report on the working of coal at Culross that

> 'The main coal seam under the subjects Nos. 206, 207, 208 and 210 on the Ordnance Survey map, and for some distance southward therefrom under the foreshore has been worked out, leaving only small pillars for the support of the surface. The working was done by Sir George Bruce and his immediate successors and was completed before the year 1676.'

Gemmell cannot have had access to the workings, so that his report cannot be based on personal observations, but as a technical expert he is unlikely to have made this statement without good reason. It can be taken, to a limited extent, as confirmation of the indications that Bruce's colliers worked the room and pillar method. Taylor (1630) hints at the same thing more picturesquely when in some of his verses he says

> 'There young and old, with glim'ring candles burning,
> Digge, delve and labour, turning and returning,
> Some in a hole, with baskets and with baggs,
> Resembling furies in infernal haggs.'

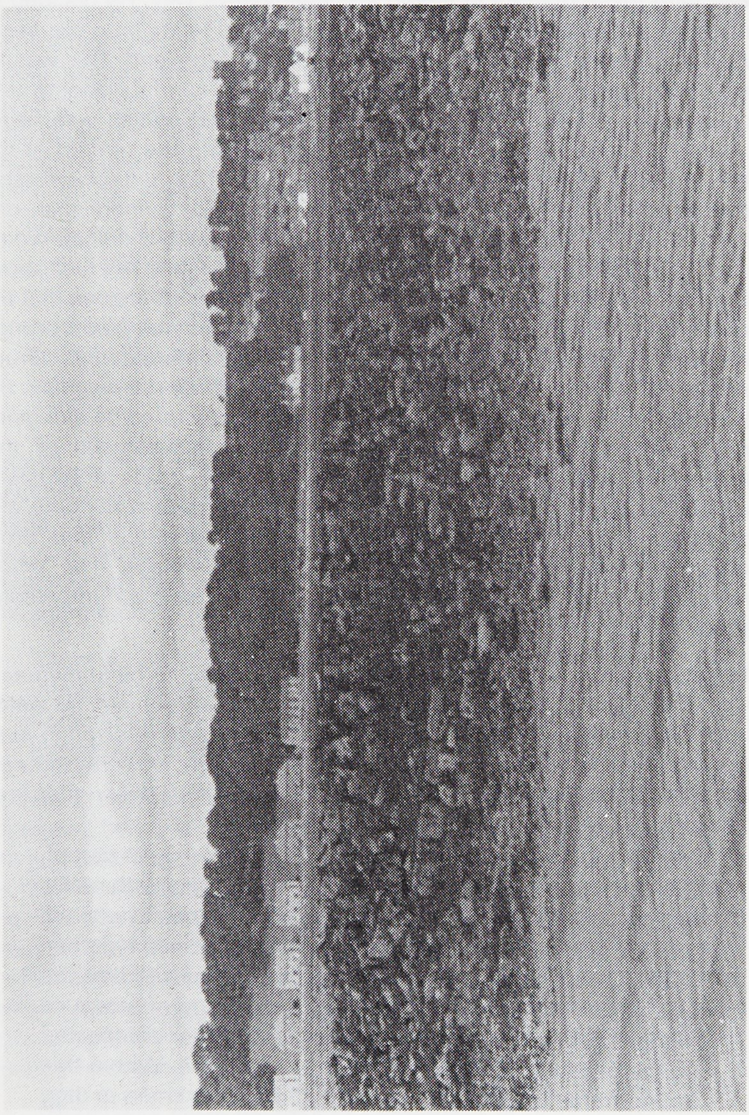
The 'hole' is a layman's reference to the 'room', and fits in with the 'many nookes and by-ways' of his prose account, to suggest working by the room and pillar method. In addition to its reference to the working of the coal, this extract is of interest as giving information about lighting in the mine. The use of candles — naked lights — suggests that gas was no serious problem in the workings, although, as candles were widely used in mines at this period, it cannot be taken as more than a suggestion. Possibly lanterns were used in the main road, but there is no definite evidence of this. In the same passage, Taylor refers to his entrance to the workings from the Moat pit

> 'Three men there (instead of Cerberus)
> Convey'd me in, in each one hand a light
> To guide me in that vault of endless night.'

As the workings moved nearer to the lowest edge of the foreshore and the deeper water beyond it, seepage of water must have increased. The ventilation problem must have become more pressing and the problems of haulage must have become increasingly difficult. Bruce's planning dealt with these matters in a bold and imaginative way. He decided to sink a pit at the lowest point of the foreshore, directly onto the seam where it changed its course and ran back toward the land. This was an operation that had not been tried before. It required careful planning with accurate surveying. Bruce intended the main road, which was being driven southward under the shore, to connect with the bottom of the shaft — a difficult and delicate operation, but one which had considerable advantages in the way of ventilation and in providing more than one entrance to the workings. The men who were sinking the shaft would have to be protected by an enclosing wall high enough to rise well above high water. Spring tides in that part of the Forth rose 15 feet, so that the containing wall would have to be at least 20 feet high, to allow for rough weather. The wall would have to have a solid foundation. Bruce envisaged an artificial island which would both strengthen the foundation and also provide facilities for coal ships to come alongside and load the coal direct from the shaft. The advantages of this arrangement were twofold: the water on the southern side of the island would be deep enough to allow ships to come alongside at any time, and the direct loading of the coal would obviate laborious and time-consuming haulage underground and on the surface. The whole conception, with its breadth and enterprise, was an impressive demonstration of the calibre of Bruce.

The type of pit which Bruce proposed to sink came to be known as a 'Moat Pit', from the fact that it was 'moted', or surrounded by water. Bruce's pit was the first to be given this title and is so referred to in all accounts. It is possible that Bruce orginated the term. No contemporary account of the sinking of the pit has been found. Taylor's description is as follows

> 'At low water, the sea being ebbed away, and a great part of the sand bare, upon the same sand (being mixed with rocks and cragges) did the master of this great worke build a round circular frame of stone, very thick, strong and joined together with glutinous or bitumous matter, so high with all that the sea at the highest flood, or the greatest rage of storm or tempest, can neither dissolve the stones so well compacted in the building, or yet overflow the height of it. Within this round frame (at all advantages) he did set workmen to digg with mattakes, pickaxes and other instruments fit for such purposes. They did dig forty feet downe right into and through a rocke. At last they found that which they expected, which was sea-cole.'



Moat Pit Culross, island from the south, Culross behind

It is safe to assume that Taylor's account is based on information received from Bruce himself, or from some of his assistants, so that it carries a certain amount of credibility. It is interesting to note the types of implement used in the sinking of the shaft — primitive, but apparently able to do the job. Taylor, however, as a layman, could not be expected to appreciate the technicalities of the operation. His account leaves some questions unanswered — about the foundations of the wall, the method of constructing it, its immediate surroundings. Fortunately, it is possible to supplement this account by an inspection of the remains of the island and the wall. This can be done only at low tide, when they are sufficiently exposed to be examined in detail. Even then, the approach is difficult, over heavy, clinging mud, in which care in choosing one's steps is advisable.

The 'island' is simply a mass of stone and mud rising a few feet above the surface of the water at low tide. On the north side there is an area in which pebbles preponderate. It looks as if an artificial beach had been created. The island forms a small tumulus. At its peak, in the centre, are the remains of a circular wall about 12 feet in diameter. The remains consist of blocks of dressed stone about 36″x 12″x 12″. There are enough of them to make it possible to trace out the whole circle. These stones must be the highest remaining part of the pit shaft wall. As they are covered at high tide, they must have had other courses above them, to clear the water level. Numerous stones lie on the lower part of the island: they probably came from the upper courses of the wall.

The space inside this wall, which must have formed the pit shaft, is choked with rocks and mud so tightly packed that it is possible to stand on it without danger of sinking in. About four feet beyond its outer perimeter are the remains of another wall, also made of blocks of stone, but with traces of a wooden lining about an inch thick at the points where it is visible. At intervals round wooden stumps appear. The purpose of these is not clear. It is likely that this second wall was the one referred to by Taylor, inside which the shaft was dug. The wooden lining could have been a temporary revetment to hold the shaft walls until they could be lined with stone. This was, and still is, a common practice in sinking shafts. Examination of the shaft, if it could be done, might yield some interesting information about 16th century methods of shaft-sinking in Scotland. In this case the wooden lining may have gone all the way down. The wooden stumps could have been pegs for ladders to be fastened on, for the use of labourers clearing the debris from the digging, or for excavators to go up and down. The pegs might even have been supports for small platforms set at various stages and connected by ladders. This was a common arrangement in Scottish pits at a later period. It is possible that when the stone wall of the shaft was built the platforms were

Moat Pit Culross, part of the inner wall extended inside it with the ladders still connecting them. It is also possible, and perhaps more likely, that a bucket and windlass were used for raising and lowering in the shaft. This would be more efficient from the point of view of bringing the coal up expeditiously, and would be in keeping with Bruce's propensity for using mechanical devices.

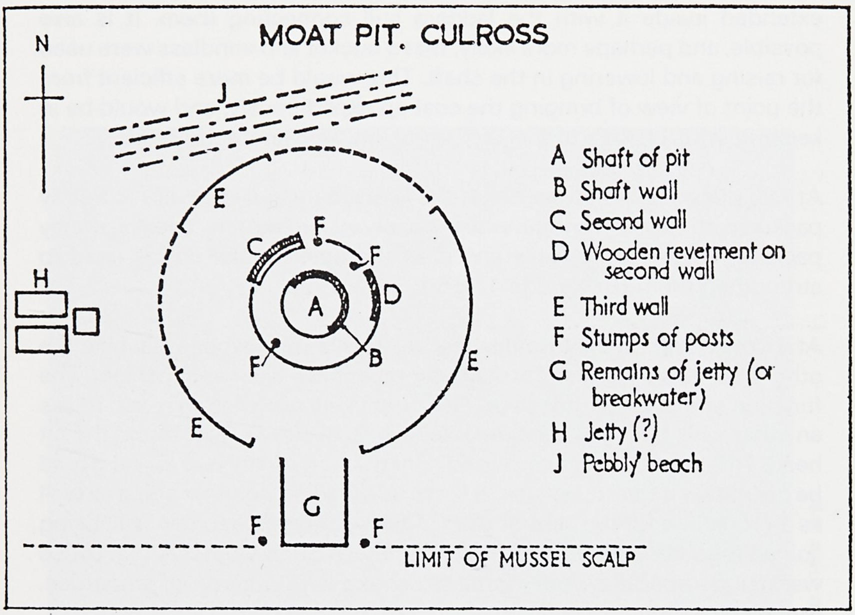
At two places it can be seen that the space between the walls is tightly packed with clay. Beveridge, who probably visited the site, speaks of 'clay packing' between the walls and is of the opinion that it was used to strengthen them (Beveridge 1885 II 311-312).

At a lower level on the tumulus are traces of a third stone wall. Like the other two, it was circular: its diameter must have been aout 50 feet. The function of this wall is not clear. The most likely explanation is that it was an outer wall, built to a considerable height, to carry a floor round the pit head. This would imply a fair-sized construction on the island and would be necessary if the island was to serve as a loading point for ships as well as a protection for the central shaft. Taylor's reference to this wall being 'joined together with glutinous or bitumous matter' suggests that Bruce was using a special type of mortar or cement with waterproof properties. Beveridge says:

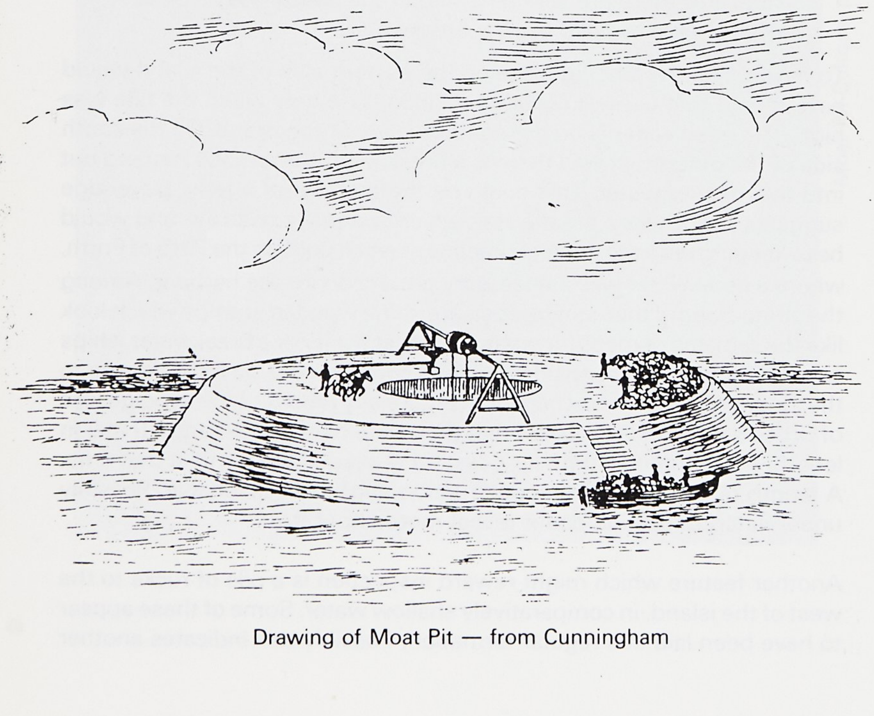
> 'The landing place is supposed to have been on the eastern side, and there are also remains on the south west side of what seems to have been a breakwater.'

To have made the landing place on the eastern side of the island would have meant that vessels could come alongside only when the tide was high. The deep water is on the southern side of the island. On the south side of the outermost wall there is a break, with stone slabs running out into this deeper water. This could be the remains of a jetty. Beveridge suggests that it was a breakwater, which is equally possible, and would be in keeping with the general practice at small ports in the Firth of Forth, where a breakwater was a necessary protection for the harbour. Among the stone slabs of this construction are some wooden stumps which look like the remains of mooring posts. Whether a jetty or a breakwater, ships could have moored alongside it to load coal. There is no indication as to the length of the construction, nor is there any record of the average size of Bruce's ships. It is probable that they were between 30 and 50 feet in length — a common length for coasting vessels in the Forth at that time. A length of 60 feet for the construction might be reasonable. Possibly underwater inspection could reveal more about it.

Another feature which might reward inspection is a pile of rocks to the west of the island, in comparatively shallow water. Some of these appear to have been laid in a regular formation. Possibly this indicates another



Plan of Moat Pit — by Bowman



Drawing of Moat Pit — from Cunningham

construction. John Cummings in 1705 stated that there were:

> 'two sinks within the sea at Castlehills, the one a dip, the other an out bearing door, also moted, it not being far within the sea.'

He refers also to a water mill with chain and bucket for raising the mine water in the pit, stating that the water to work the mill

> 'was carried in long troughs from Castlehill to the Mote'.

The 'out bearing door' was obviously the shaft whose remains are to be seen at the top of the island. The other 'sink' seems to have been used for draining the workings by means of a water wheel carrying a chain with buckets for dredging. The location of this water wheel with its shaft going down into the workings does not appear in any account of the mine, but it was clearly intended to cover the area around the pit bottom of the Moat Pit, which would be particularly wet. It is possible that the pile of rocks on the west side of the island has some connection with this wheel and its shaft. It might be the remains of a foundation for the water wheel referred to by Cummings. The drainage shaft however, would almost certainly have had to be on the island, with its mouth above high water mark. This raises the question of why Bruce did not employ another Egyptian Wheel, driven by horses. It is interesting to note that in an article on the mine in the *Wemyss Magazine* of 1910 there is a drawing by W.H. Shepherd purporting to indicate what the island was like. It shows a horse gin working on it. What grounds the artist had for including this feature in the drawing are not known, but it is not difficult to find reasons for a horse gin **not** being used.

It would have been hard to take horses over the heavy mud of the foreshore at its lower part, although they might have been transported by boat. Stabling on the island would have presented problems. So would taking them to and from it according to the tide. Space on the island must have been limited and it is doubtful if it could have provided enough room for even one horse to drive a wheel. While it would not necessarily be ruled out for a man of Bruce's ingenuity and ability, the evidence points to his having had resort to a different, and characteristically bold, device, adapted to deal with the problems presented by local topography. He decided to instal a wheel driven by water brought from Castlehill by means of a trough. He had already had some experience with troughs in disposing of surplus water from the Egyptian Wheel, but this was a much more ambitious project. He went back and up from the Castlehill pithead to the moor above it, where the Dean Burn ran over the edge into a gully which carried it down to the shore. He dammed the Burn at this point and brought the water through a sluice gate into the troughs which conveyed it for the better part of a mile to the water wheel at the Moat Pit. This in itself was no mean feat. It would call for careful grading of the fall of the trough, to ensure that the flow of the water was sufficiently strong to drive the wheel. The construction of the supports for the troughs must have been a difficult operation in the upper reaches and also on the deep mud of the foreshore. On the evidence of John Cummings, however, and of proceedings relating to the destruction of the dam, there can be little doubt that Bruce accomplished his exacting task and drove his water wheel successfully. When the whole apparatus came to grief, it was due to a hostile human agency, and not to any technical weakness. In 1607 some local men, led by one John Gaw, who was a notorious disturber of the peace, broke down the dam and destroyed the water course. Bruce lodged a complaint with the Privy Council

> '....... Upon 6th, 7th, 8th and 9th January last the said Johnne Gaw came with his servants to the wattir passage that discendis from the said complenairis wattir dammis in the common muir of Culrois to the wattir myle of his coilheuch within the sey mark and set the wattir of the said dame by the accustomet course and ganging quhilk it has evir had in all tyme bigane past memorie of man of purpoise to drawe the wattir althegither fra the complenairis coilheuch' (RPC VII, 1607, 189).

Finding this somewhat difficult, Gaw resolved to destroy the dam and thereby compel the complainant to

> 'interteny horse and man for that service of his heuch quhilk before was done by wattir ......'

There follows a description of how John Gaw of Maw, John Dick of Coquhallie (in Easter Gartmore) and eight others, armed with lances, held the dam on Sunday, 25th January, and

> 'cloisit in the wattir at the clouse of the said complenairis dam, of purpois to hald in the wattir unto the time appointit be him for dimolisheing and breking doun the dam, that the wattir mycht have the grittair course and waygang.'

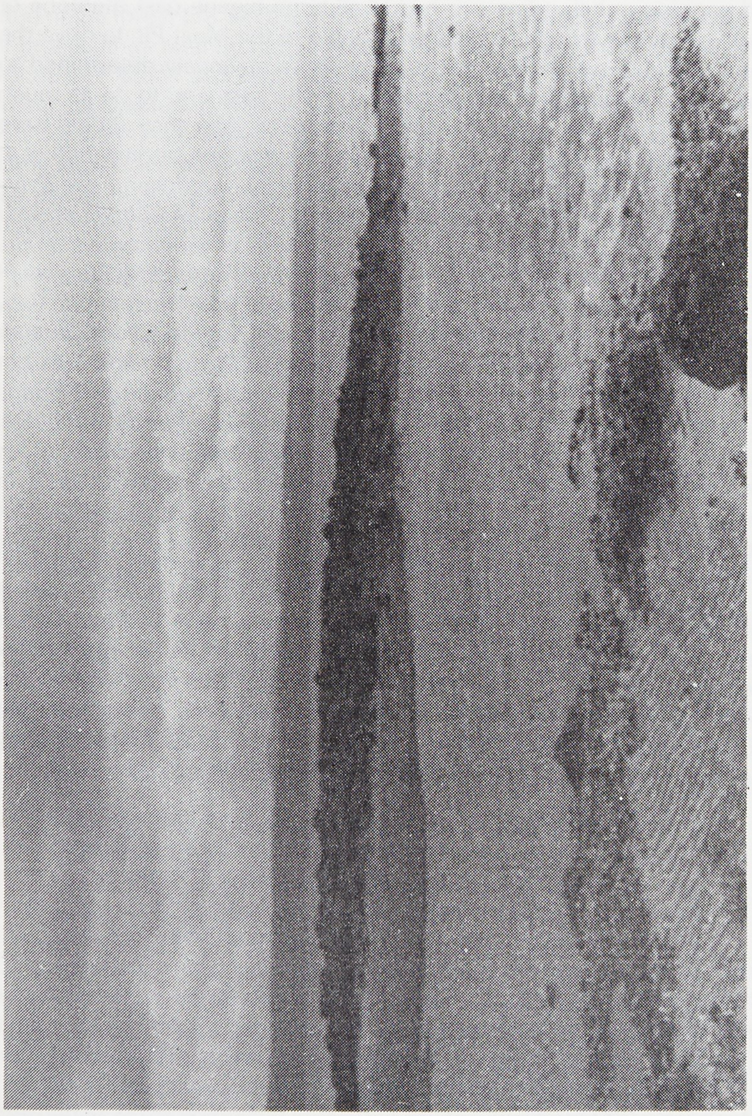
On the following day Gaw and his companions broke the dam and ran away the water which, Bruce complained, would have served him 'till Whitsunday next'. Gaw and Dick were bound on security of £1000 each not to harm George Bruce of Carnock.

The details of the complaint show that Bruce had dammed a water course on the Moor of Culross and had piped the water to a water wheel at the Moat Pit — 'the wattir myle of his coilheuch within the sey mark'. At the point where the Dean Burn comes down from the Moor of Culross there is a saucer-like area which might well have been the catchment of a dam. On its southern side are traces of what seems to have been a stone wall. This, in all probability, was the dam built by Bruce, with which he diverted the water of the burn from its natural course — 'the accustomet course and ganging quhilk it has evir had in all tyme bigane past memorie of man' — into the troughs which led it down to the Moat Pit, to drive the water wheel. Gaw and his companions were obviously determined to make a thorough job of the demolition of the dam and to do as much damage as possible by the release of the water. Why they should have had this malicious intent is not stated, but it is perhaps significant that at about the same time as Bruce was making his complaint, the Privy Council had a complaint from the Bailies and Council of Culross against John Gaw of Maw and others for causing trouble in various ways on the Moor of Culross (ibid XIV, 1607 408). Bruce was the leading Burgess of Culross and a prominent member of the Council. It is possible that Gaw and his associates were taking a spiteful revenge upon him. Whatever their motive, they seem to have done a great deal of damage. It is not known whether it was too great to make it worth repairing. It seems unlikely that a man of Bruce's spirit would allow the broken dam to be left unrepaired, but the incident must have caused immediate difficulties over drainage in the mine workings around the bottom of the Moat Pit. In spite of the heavy security on Gaw and Dick there was no guarantee that the working of the water feed to the wheel would not be impeded again. Bruce seems to have looked for an alternative source of power.

His statement that Gaw intended him to 'interteny horse and man for the service of his heuch' suggests that Bruce might have been prepared to work the wheel at the Moat Pit by a horse gin. There is, however, no evidence that he did so. There is some reason to believe that he experimented with water wheels driven by the tide. Sir Robert Moray, writing in 1658 to Alexander Bruce, 2nd Earl of Kincardine, said

> 'I remember before to have heard of your Grandfather's Tyde Mills. I do indeed remember to have been into the Moat at Culross when the coal was going there some 35 years ago — but I believe you do not think of recovering that Moat again. One thing you can tell me — whether these Mills that went with the Tyde drew water from your coals or not ...... I find that these 4 Tyde Mills have all been employed to dry the coal you aim at together with one wind and one horse mill, but all could not do it. Before we can compute what your intended aqueduct can do more than these .... there must be talks for paper' (Elgin Archives).

Both Sir Robert Moray and Alexander Bruce were founder members of the Royal Society. It is not surprising, therefore, to find them



Moat Pit Culross, island at low tide, looking south correspondence over a technical problem of mine drainage. The implication of Moray's reference to George Bruce's 'tyde mills' is that they could have been used for draining the workings at the Moat Pit. The latter part of the passage suggests that such devices were tried elsewhere with no success, even when combined with a wind mill and a horse gin similar to Bruce's Egyptian Wheel. The tide mill was not an original device. Tide mills were in use as early as the 11th century, although their greatest use was in the 18th. They were never very effective as sources of power. A common form of tide mill consisted of two boats or pontoons moored in a tideway with the water wheel on an axle between them. If Bruce's tide mills were of this type, it is difficult to see how they could have worked a drainage apparatus at the Moat Pit, except, perhaps, by an elaborate system of cogs and axles. The unexplained pile of stones to the west of the island might have had some connection with such an apparatus. The reference to an 'intended aqueduct' in Moray's letter suggests that the Earl of Kincardine may have been thinking about emulating George Bruce's water troughs from Castlehill, and this in turn might imply that greater power was to be obtained from water piped this way.

As far as George Bruce's tide mills are concerned, there is nothing to show whether they were effective or not, but it would be in keeping with what we know of him if he had tried to make use of the ebb and flow of the tide to drive water wheels for the drainage of the Moat Pit. The matter is one which might bear further investigation around the site. The destruction of the dam on the Moor by Gaw and his men certainly did not put a stop to the working of the mine, which continued for another 18 years under the lower part of the shore. It is possible that the tide mills were tried as the workings moved east, to deal with local drainage and ventilation, as a supplement to the work being done by the water wheel.

With the completion of the Moat Pit and its island the main construction work on the Colliery was finished. If Taylor's statement is accepted, that it had been operational for 28 or 29 years in 1618, then the Colliery must have been in full production by 1590. Not long after this Bruce is believed to have purchased the Colliery, which he had been working on lease, and to have been granted monopoly rights in coal and salt production at Culross (Laing Charters 6 and Register of the Great Seal (RMS) 1598 816). The Colliery continued in production for another 35 years. Gemmell (1909) in his Report estimated that the workings could have 'reached eastward from Sir George's Moat to a point near the Bucket Pat now the Fish Pond'. The Fish Pond is about a mile east of the Moat Pit, so that, if Gemmell's estimate is correct, there must have been considerable working of coal east of the fault and away from the direction of the main Jenny Pate seam. This is to some extent borne out by the statements of John Cummings and others, made in 1705 (Elgin Archives), but whether it was done in the time of Sir George Bruce is not clear.

The working of the Colliery was brought to a sudden halt at the end of March, 1625, when a particularly violent storm breached the defences of the Moat Pit and flooded it. Bruce died soon after. His son George, who had for some time been in charge of day-to-day working, took over full direction of the Colliery, but with the sea in the workings of the Moat Pit it was impossible to continue production there. Presumably the seam between the Castlehill Pit and the Moat Pit had been largely, if not completely, worked out. Some of the area to the east of the Moat Pit as far as the fault may have been worked out also. On the eastern side of the fault the coal was not so deep as in the Moat Pit area and it is reasonable to suppose that it was little affected by the flooding from the breach of the Moat Pit. The Geological Survey Map shows several abandoned pit shafts along the shore at the east end of the Culross (Geological Survey of Scotland 1921, Fifeshire, Sheet XXXVII SE). These are the pits which John Gemmell had in mind when he stated that Bruce extended his workings as far as the Fish Pond, at the east end of Culross. Gemmell supposed that all these workings were connected underground and were flooded when the Moat Pit was destroyed. He suggested that the Moat Pit was filled up and made watertight at the surface, sealing it off from the rest of the area, and that these eastern workings were continued up to 1676, the water being kept down by pumping. Gemmell referred to statements by John Cummings to support this theory, which is a not unreasonable one. His idea that the Moat Pit was made watertight at the surface might be confirmed by the fact that it is possible now to stand on the central area of the pit shaft.

More recently, however, an official of the National Coal Board has questioned the possibility of sealing off the Moat Pit once the sea had got into it. Mr. W. Rowell, Alloa Area Manager, in a letter to Lord Bruce dated 2.11.1962 (quoted with permission of the Earl of Elgin) has commented

> 'Making the Moat Pit watertight after the destruction of the 'island' would probably be beyond even modern techniques and, in any case, the sea was in the working. It is almost certain that as a result of the storm damage the Moat and Castlehill Pits would have been abandoned.'

Gemmell and Rowell are in agreement that the main workings of Sir George Bruce's Colliery, in the bords leading from the main road between the Castlehill Pit and the Moat Pit, were rendered unworkable by the storm of

1625. Most of them must have been worked out by that time so that their unworkability would be no serious setback. What is not clear is the extent to which the coal to the east of the Moat Pit was affected. It is not known how far Sir George Bruce had taken development in this direction. Without this knowledge it is difficult to assess how far east the flooding of the workings would have gone. The statements of John Cummings made in 1705 (Elgin Archives) are the only account of the workings to the east of the Moat Pit, and they are largely hearsay evidence; but they are nonetheless worth considering as a pointer to developments after 1625.

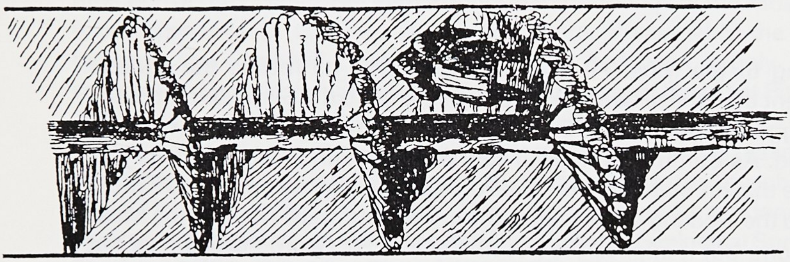
Referring to the Moat Pit and the Water Mill he makes the curious statement that 'these two sinks wasted very far to the SW within the sea'. This suggests a direction of the workings quite opposite to what might be expected. As Cummings himself cannot have seen these workings it is possible that his statement is based on exaggerated accounts and simply refers to the working of the coal to the immediate south-west of the Moat Pit bottom; but it implies the possibility that Sir George Bruce may not have taken his workings as far east as Gemmell maintains. Cummings (1705 Elgin Archives) speaks of

> '...a sink within the sea mark at the full sea to the east of B. Wilson's south yard to the south of the Causey and he thinks that there was a Mote a dipping thereof within the sea but he knew nothing of this but as he was informed... There were several sinks at the mark drawn between B. Wilson's and Castlehill Lands...'

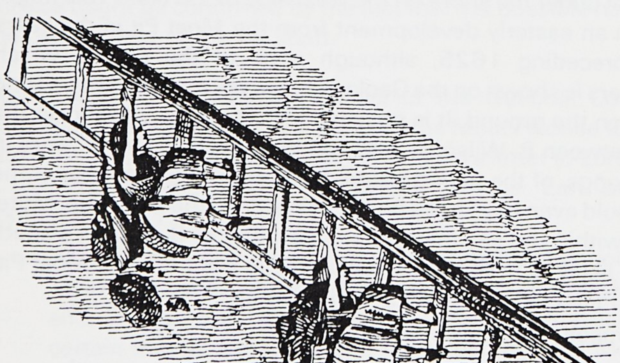
This must refer to the Blairburn area and suggests working of some of the Jenny Pate coal under the shore on the west side of the fault. This might just have been an easterly development from the Moat Pit in the years immediately preceding 1625, although none of the pits to which Cummings refers is shown on the Geological Survey map, and there is no trace of them on the ground. It is possible that the 'severall sinks at the mark drawn between B. Wilson's yard and the Castlehill Lands' were in fact early workings, of the period before Sir George Bruce's lease of the Colliery and could even have been on the east side of the fault. The 'Mote' and the 'sink within the sea mark' at the east end of B. Wilson's south yard are more likely to have been developments from Bruce's Moat Pit, on the Jenny Pate coal to the west of the fault.

Cummings himself, as a child, saw

> '...a Mote opposite to the Hospittal, the water drawn with Horses and there was a sink or air Hole on the Land at the E. end of the House on the South Side of the Gate in which hole was one of the Sink Ladders upon which they went up and down and that he saw the Bearers bear coals at it...'



Spiral stair — from Cunningham



Coal bearing and dangers — straight ladder

The coal being worked at this pair of pits must have been the Jenny Pate on the east side of the fault, where the seam came in from the Moat Pit. The Hospital was at the west end of the Sandhaven, near the harbour. It is interesting to note the pair of pits being worked together, a moat pit and a land pit. The moat pit must have been higher up the shore than Bruce's which would explain why it could be drained by a horse gin. As it was working when Cummings saw it — probably in the late 1630's or early 1640s — it could have been developed by Bruce's son George, after the destruction of the Moat Pit in 1625.

The mention of ladders in the landward pit is the only reference to this means of ingress and egress in the mines at Culross. If it was used in the pit at the Hospital, it is likely that it was used in at least some of the landward pits, and possibly also in some of the moat pits. Cunningham (1913) speaks of a spiral stair having been commonly used in pit shafts in Fife. Some of the pits at Culross may have been fitted with this equipment, but there is no evidence of it.

Cummings (1705 Elgin Archives) is reported as stating that

> 'There is a sink on it at the back of B. Barclay's House at Culross Pans. He knows not how deep it was, but that all the water was drawn with a Horse Engine and was pended in the mouth but as he was informed the Brae shot and broke the Pend and overturned the whole work. He saw it go when he was 10 years old or thereby...'

This must have been about 1643, Cummings having been born about 1633. Barclay's Pit was at the extreme east end of Culross. A pit called the Engine Pit was on the shore near it. Probably these two were working together when Cummings saw them. A little west of this was another pair of pits, described by Cummings (ibid)

> 'There was a sink on it opposite to the E. end of the Convent Yards within the Sea in a Mote at the North end of Culross Pans, at which Mote the water was drawn with a Horse Gin, as also there was an outbears sink on the land at the E. end of the Sleep of the Kiln at Mary Cunningham's House and which afterwards belonged to J. Sands and is now burnt. He knew nothing of this but as old people told him.

These accounts by Cummings show a pattern of mining very similar to that developed by Sir George Bruce — a pair of pits, one on land well back from the water, the other on the shore, subject to isolation as the tide came up. These workings suggest that they were developed by Sir George Bruce's son George in the decade immediately following the disaster to the Moat Pit. The impression given is that George Bruce, the son, directed his attention to the coal lying on the east side of the fault, and to some seams that appear to have been under the eastern part of the Culross foreshore. Cummings mentions also

> '..a Sink set down at the Strand upon the south end of the Causey on the land the Strand rimes (?) exactly to sea upon west end of the land. This was told him by old People and that the sea came in upon it and overturned all.'

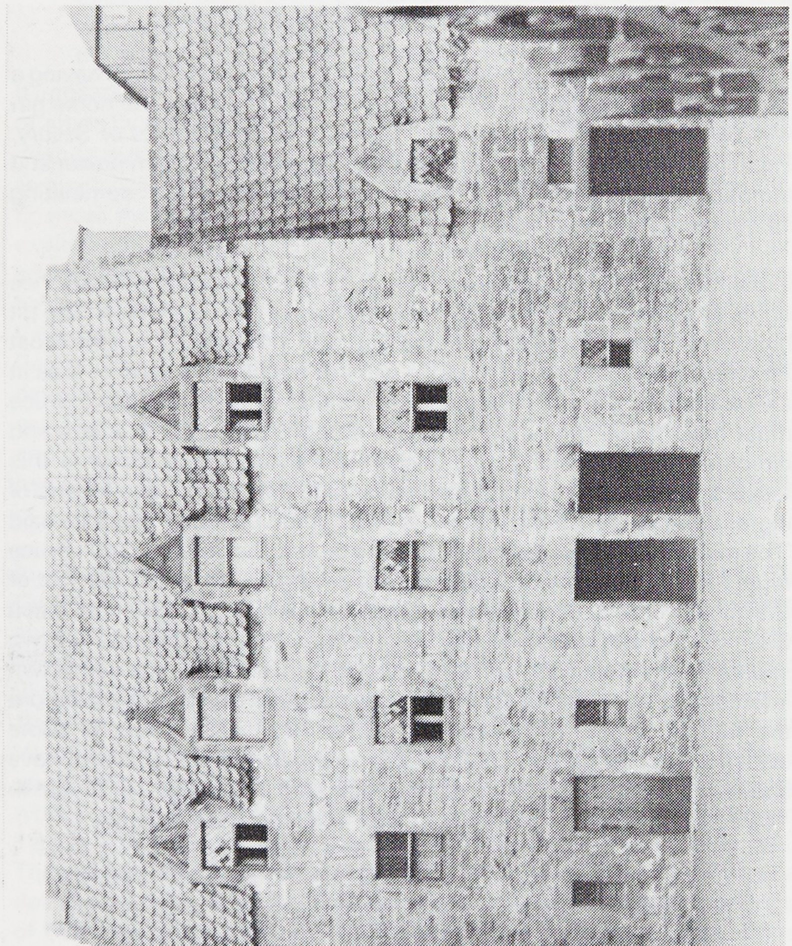
It appears from the statements of Cummings that all these pits were out of action by the middle of the 17th century. It is unlikely that they were as deep as those worked by Sir George Bruce on that they had anything like as much coal. The use of horse gins suggests that George Bruce, the son, financed them. The pits would all come under the monopoly of mineral exploitation granted to Sir George Bruce. George the son probably feued some of the land to mining contractors. Cummings speaks of his father having started a mine in the Convent Yard, driving east towards Valleyfield, and he states that the Earl of Kincardine (a grandson of Sir George Bruce) put down the 'Dingdong Sink' onto the same seam. No date for this is given, but it indicates that the local mining was moving east in the direction of Valleyfield after the finishing of the pits at the east end of Culross. Gemmell, in his report, states that coal working at Culross had ended by 1676. The evidence of Cummings suggests that the bulk of it had ended before the middle of the 17th century.

In the picture of mining at Culross which emerges, the Colliery of Sir George Bruce is the dominant feature, with its novel technology making an impact upon the lesser workings that followed the disaster to the Moat Pit in 1625. The practices of using the horse gin for drainage and the moat pit for getting at coal under the sea were taken up elsewhere along the coast. As early as the end of the 16th century Lord Sinclair, at Wemyss, was developing coal working under the sea in this way. There is some fairly reliable evidence that miners at Wemyss did some shallow working of coal under the low water mark as early as 1557 (Cunningham 1913). It did not extend far, however, and did not reach the deeper coal. There is no evidence that Lord Sinclair's later workings were a development from this. Indeed, the evidence suggests that the workings of 1557 had been forgotten. Their discovery in 1657 was accidental. It is not clear whether Lord Sinclair's workings were developed independently of Sir George Bruce or in consultation with him, but the weight of tradition lies in favour of Sir George Bruce being the pioneer in this type of mining and it is not unlikely that Lord Sinclair followed his example. That example seems to have penetrated also to Valleyfield, where the Preston family were interested in coal mining and had a moat pit working in the early 18th century, and possibly earlier. Sir George Bruce's son George married Mary Preston of Valleyfield. It is reasonable to assume that his experience of moat pit workings and drainage by horse gins was put at the disposal of the Preston family in their development of the coal working at Valleyfield. By that time the horse gin was being used in collieries outwith the Forth Valley. This was an important factor in the exploitation of deeper workings.

Bruce's demonstration of how to get at the lower measures was having a marked effect. By the start of the 18th century, however, the horse gin was generally being used for coal raising. The experiments of Savery, Papin and Newcomen with pumping engines in which steam power and atmospheric pressure were used were becoming the dominating influence in mine drainage.

In the matter of ventilation Bruce's practice was considerably in advance of his time. As has been stated, the difference in levels between the pit bottom at Castlehill and those of the Egyptian Wheel shaft and the Moat Pit would create a through draught without the need for fans or fires at the pit bottom. There is no evidence that either of these was used. Bruce must have found the natural through draught adequate. The size and directness of his main road probably was an important factor in this respect. There was the additional advantage that it gave two means of ingress and egress to the mine — a point noted by Taylor when he said 'The mine hath two wayes into it, the one by sea, the other by land'. Bruce must have appreciated the advantage of having an alternative way out of the mine in case of underground accidents. It is interesting to note that it was not until the middle of the 19th century that the provision of two separate exits was made compulsory in Britain, and even the use of two interconnected shafts for ventilation was not generally recognised before the middle of the 17th century (Griffin 1971 63). There is some evidence that Bruce was proud of his arrangement. He is said to have shown it to King James VI when the King paid a surprise visit to him in 1617. The incident is recorded in the first Statistical Account –

> 'There is a tradition that James VI, revisiting his native country, made an excursion into Fife, and, resolving to take the diversion of hunting in the neighbourhood of Dunfermline, invited the company then attending him to dine along with him at a collier's house, meaning the Abbey of Culross, then belonging to Sir George Bruce. Being conducted by his own desire, to see the works below ground, he was led insensibly by his host and guide, to the moat above-mentioned, it being then high water; upon which, having ascended from the coal-pit, and seeing himself, without any previous intimation, surrounded by the sea, he was seized with an immediate apprehension of some plot



The Palace, Culross at July 1964

> against his liberty or life, and called out, Treason, but his faithful guide quickly dispelled his fears, by assuring him that he was in perfect safety; and pointing to an elegant pinnace that was made fast to the moat, desired to know whether it was most agreeable to his Majesty to be carried ashore in it, or to return by the same way he came; upon which the King, preferring the shortest way back, was carried directly ashore, expressing some satisfaction at what he had seen' (Sinclair 1794)

Sinclair is not correct in interpreting James VI's remark about 'a collier's house' as referring to the Abbey of Culross. In fact, Sir George Bruce lived in the large mansion at the Sandhaven known as 'The Palace'. The house is an interesting example of late 16th-early 17th century Scottish domestic architecture. It reflects both the personality of Bruce and his rise to fame and fortune. The older part, which bears the mark GB 1597, is a relatively modest building. Its date suggests that Bruce had it built when the main part of his mine development programme was completed and when the creation of the town into a Royal Burgh had been confirmed. His taking up residence in the Sandhaven may have had some connection with this. The later part of the house, marked SGB 1611, is a much more pretentious building. It is in this part that the impressive vaulted strong room is situated. Above it are public rooms and bedroom suites which must have been spacious and comfortable by the standards of the day, with panelling on which can still be seen the painting which decorated them. The initials 'SGB' on the building are thought to represent 'Sir George Bruce'. The date of Bruce's knighthood has not been clearly established. 1604 has been generally accepted as the year in which he was knighted. The authority for this is *Reliquae Culrossiae,* by T. Etherington Cooke, but the source of his information is not known. In certain state papers between 1604 and 1610 Bruce is referred to without the title of 'Sir' (RPC VII 1604-1607 and VIII 1607-1610). In 1610, however, he is referred to as 'Sir George Bruce', having charge of his Majesty's Works at the Mines (RPC IX 1610-1613). It is reasonable to assume therefore that by 1610 Bruce was a knight. It is possible that the extension of his house was not unconnected with his becoming one. An interesting feature of this extension is the typical Scots windows of the period, with fixed leaded glass above and wooden shutters below. The title of 'Palace' is thought to have been applied to the house after the visit of King James VI.

In view of his services to his country and in particular to Culross, Sir George Bruce's knighthood was well deserved. He was a hard-headed businessman and a firm supporter of law and order, but he was also a humanitarian with a practical interest in those who worked for him. Dundonald's remarks about his attitude to the colliers suggests an employer with a sense of responsibility for those who worked for him, and his own remarks in the preamble to the complaint against John Gaw and others indicate that he had some appreciation of the importance of steady employment to the workers under his control. Although little is known about Bruce's labour relations, such information as we have points to an imaginative and liberal attitude which was far in advance of its time. It is likely that in the early stages of the development of the mine he was very much in touch with the men who were doing the work. As has been stated, his employment of local colliers in this work instead of miners would necessitate a close personal supervision. His decision to use the Culross colliers may have been grounded on expediency — it was probably cheaper to employ local men and easier to recruit them — but to obtain good work from them would require good leadership. This must have been where Bruce's personal contacts with the work force had effect. His organisation of the Colliery as a technically-efficient company employing local labour on some scale must have represented a considerable advance on the previous position at Culross, where small mines were worked by a few colliers in the employment of the feuers of the coal. The salt making and iron founding industries which he developed were offshoots of the mining organisation and were ancillary to it, culminating in Bruce's obtaining the monopoly of these industries at Culross at the end of the 16th century and the beginning of the 17th.

In the initial stages of the mine, according to Dundonald (1793), women were not employed. Dundonald points out the interesting social result of this: the women stayed at home and looked after the house and the children. This had a marked effect upon the colliers, who became notable among other colliers for their sobriety and responsible behaviour. The squalour and poverty which marked the homes of other colliers must have been largely absent from those of Bruce's employees. This would make for a more contented and healthy work force. Bruce's unusual method of paying wages, whereby he paid only a part of them fortnightly and held back the balance to accumulate and be paid quarterly, suggests an employer who had the interests of his employees at heart, although in the years before the Act of 1607 it might have been a means of preventing the colliers from leaving his employ. This was the main reason for a somewhat similar practice in the payment of wages of Scottish agricultural labourers right up to the 19th century.

By the beginning of the 17th century the main development of the mine had been completed and Bruce seems to have delegated its immediate management to his son George and to have become involved in affairs of state and public service. By this time his business was thriving, with ramifications which must have required his personal attention from time to time, but it is likely that his relationship with the workers in the mine was not so close as it had been. There is some ground for belief that George Bruce, the son, had a similar attitude towards the workers as had his father and that he was concerned with their welfare. In 1639 he founded a hospital at Culross for the maintenance of widows of colliers and salters. It is doubtful if he or his father availed themselves of the provisions of the Act of 1606 which bound colliers and salters to their place of work and gave the employer powers to deal with them as serfs. This would have been quite out of keeping with what is known of their attitude to their workers.

By the time of the visits of James VI and John Taylor to the mine its main features were well established and must have presented an outstanding and unusual spectacle on the shore at Culross. In the forefront, rising out of the water, was the island, with coal vessels lying at the jetty or breakwater or anchored out in the roads beside it. Loading at the island must have saved a considerable amount of time, trouble and expense. Indeed, the importance of the island lay as much in this feature as in its protection of the mine shaft. Near the island perhaps were the tide mills, geared to a chain and bucket apparatus on the island for draining the Moat Pit. This apparatus could have included the wheel driven by the water brought down in troughs from Culross Moor before John Gaw and his men destroyed the dam. Up on the higher part of the foreshore the great framework of the Egyptian Wheel would be seen, its three horses plodding round their track as the wheel turned slowly and the buckets came up to pour their contents into the troughs leading to the salt pans and the sea. In the back-ground, under the hillside, the Castlehill pithead would be discernable. The whole was the symbol of Culross's prosperity.

So far, no Colliery records of production have been found. To judge from the various uses to which the coal was put — for salt making and iron smelting and, latterly, glass making, for sale to towns and for export to England and the Continent — production must have been steady and considerable by the standards of the day. Taylor (1630) speaks of 90 to 100 tons of salt a week being made. This must have required a large amount of coal. Records in the Exchequer Rolls of Scotland (XXI — XXIII 1580-1600) give some indication, although limited, of the production of coal and salt for export. There are no figures of export of coal for the years 1575–1579, from which we may conclude that the Colliery, still under development, was producing for home consumption only. 1580 was the first year in which coal exports from the Colliery were recorded. 406 chalders were produced for export. The exact size of the chalder is uncertain, as it seems to have varied from place to place. Later, when the measure was standardised at about two tons, it was said to have been based on the Culross chalder, so it is reasonable to assume that Bruce's chalder was of this amount. The production of 800 tons suggests that by

1580 the deeper coal was being worked. This could support the estimate that the Egyptian Wheel was brought into action about that time. It might also indicate that the advancement of the underground road had reached at least a point approximately half way between the Castlehill Pit Bottom and the Moat Pit. Export figures for the next few years fluctuate — 55 chalders in 1581, 207 in 1582, 96 in 1583. The reason for this fluctuation is not known. Figures for the rest of the decade are not available. From 1590 to 1599, however, the yearly production figures lie consistently between 300 to 400 chalders, and there is a distinction between 'smyddie coill', of poorer quality, and 'greit coill' or 'burnecoill', which was considerably more expensive and was exported in smaller quantities. The main development of the Colliery had been completed and it was possible to concentrate on production. Bruce was bringing out a considerable quantity of coal. He had a license from James VI to export a large amount of it, so that he was not liable to prosecution under the laws of the mid-16th century forbidding the export of coal. James VI, in his anxiety to stimulate Scottish trade, had been fairly generous in his issue of such licenses and by the start of the 17th century there were increasing complaints from the Scottish burghs, who felt that supplies of coal for their inhabitants were becoming insufficient. The coal owners maintained that there was enough coal for home consumption as well as for export. The burghs did not agree. James VI became concerned at the situation. In 1609 he issued orders that the legislation banning the export of coal should be enforced. At the same time he instructed the Privy Council to meet representatives of the coal owners and of the burghs to try to determine the rights and wrongs of the dispute (RPC VIII 1607-1610 and X 1613-1616). Bruce was one of the representatives of the coal owners, having in 1598 obtained from the Crown a grant of the mineral rights at Culross, which included the Colliery (RMS 1593-1608 815). The coal owners reiterated their belief that there was enough coal to meet the requirements of both home demand and export trade. After careful consideration the Privy Council agreed with them. There can be little doubt that one of the factors influencing them was the ability of the coal owners to reach the deeper coal with the help of the drainage methods and moat pits introduced by Bruce. This is a measure of the influence of his mining techniques on the expansion of Scotland's economy. It is interesting to note that the coal owners maintained that the export of coal was necessary to enable them to meet the cost of these new methods of production, and that the Privy Council made this the main reason for their support of the coal owners. Technical innovations of this kind were expensive, but were justified by their influence in improving production to meet the demands of an expanding market.

Their introduction called for a capital investment beyond the reach of the colliers who in small groups conducted most of the bell pit and 'ingaun ee' mining. The financing of the new techniques usually came from the landowners who held the mineral rights and paid for the machinery and equipment. While they probably, like Bruce, maintained a fairly close contact with the working of their mines, they must of necessity have delegated much of the detailed supervision to their own agents or to contractors. John Cummings (1705 Elgin Archives) refers to 'skilled oversmen' doing some development planning in the presence of the Earl of Kincardine and Sir George Preston. Perhaps this simple delegation marks the first steps in the emergence of a more complex organisation which in later centuries was to develop into the mining company. But the main importance of Bruce's innovations lies in their influence on problems of raising water and coal — an influence which was not challenged until the introduction of steam power for pumping and lifting. It is interesting to note in passing that the first Watt steam engine was installed at the Carron Company's Burn Pit at Kinneil, across the Forth from Culross, to pump water from the workings. Earlier, one of the first Newcomen atmospheric engines in Scotland was installed for the same purpose at Preston Island in Valleyfield Bay, east of Culross, where a horse gin was already in use. The introduction of the Newcomen engine continued the tradition of enterprise in the technology of mechanical drainage started by Sir George Bruce and probably introduced to Valleyfield by his son.

Sir George Bruce's influence on Scottish mining was felt not only in the technical innovations which he brought to coal production, but in the organisation of the operations in which the innovations played a major part. Had the coal owners been less grasping and more imaginative they might have been more widely influenced by Bruce's attitude and might have appreciated the practical advantages of giving their workers reasonable living conditions. It is not unlikely that the Earls of Wemyss and Kincardine learned something from Sir George Bruce in this field. Among his contemporaries Bruce stands out as a notable figure in industry, commerce and public service. In the annals of Scottish mining he occupies an important position in the transitional stage between mediaeval and modern coal production. The remains of the Colliery at Culross are an important relic of that stage. As such, they are worthy of preservation. The most important and most difficult to deal with are the remains of the Moat Pit and the island. Clearing of the stones on the circular walls and some excavation of the pit shaft at low tide might yield more information about how operations on the island were carried out. Exploration by divers in the water to the south of the island might reveal information about the jetty or breakwater. Other points worthy of examination are the pithead at Castlehill and the conjectural site of the dam on the Moor of Culross. Of the mine workings at the east end of Culross there seems to be no trace, but a careful examination of the area might be worthwhile. If the account of John Cummings is to be accepted as it stands, there must have been a fair amount of activity in the area, with something more than the shallow workings of the monastic times. For the antiquarian, the industrial archaeologist and the local history enthusiast the 16th and 17th century mining at Culross offers a promising field for research.

ACKNOWLEDGEMENTS

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NOTE

In 1970 I published an article entitled 'Culross Colliery: a Sixteenth-Century Mine' *(Industrial Archaeology* 7, no. 4, 353 - 373) Information obtained subsequently has made me revise my views on various points and interpret some of the evidence in a manner which at places conflicts with my earlier interpretation of it. I now believe, from what I have learned about 16th century mining surveying, that the main development of the Colliery, in the area between the Castlehill and Moat Pits, was a planned operation rather than the somewhat haphazard advance which I envisaged in my earlier paper. My interpretation of the evidence about the water wheel supplied with water from the Moor of Culross has changed also, and I have abandoned the idea that the Egyptian Wheel might have been used for raising coal.

The present paper also pays more attention to the later coal workings east of the main part of the Colliery, which were not within the purview of the previous paper, although they were given a passing notice.

In the interests of obtaining as correct and accurate a record as possible, I have felt it necessary to make these changes, even if they contradict what I have said previously.

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